EMERGING TECHNOLOGIES

Directed Energy

Information

Materials and Manufacturing

Munitions

Air Force Office of Scientific Research (AFOSR)

(Continued on next page)

EMERGING TECHNOLOGIES (CONT'D)

Propulsion

Sensors

Air Vehicles

Space Vehicles

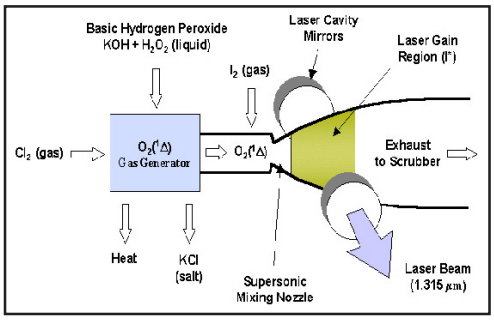
(Continued on next page)

EMERGING TECHNOLOGIES (CONT'D)

Space Vehicles (Cont'd)

COIL Technology Useable for High-Speed Cutting and Drilling

I



Payoff

Currently, neodymium doped yttrium aluminum garnet and carbon dioxide are the most widely used industrial lasers for high-speed metal cutting and other materials processing tasks. The Chemical Oxygen-Iodine Laser (COIL), however, offers distinct advantages over each of these lasers. COIL offers the potential of scaling to powers over 10 kW and delivers through fiber optics. This combination makes the COIL extremely well suited to handle high-power materials processing tasks; deliver power remotely via robotics; and eliminate the need for large-scale industrial band saws, torches, grinders, and water jets, which are generally labor-intensive, slow, and expensive. Materials processing tasks include laser cutting, drilling, and welding, as well as laser marking.

Accomplishment

Researchers from the Directed Energy Directorate investigated COIL to develop the technology to a point in which it could be transitioned to an operational system. Under a Cooperative Research and Development Agreement with the directorate, the Colorado School of Mines demonstrated rock crushing using the COIL for oil-drilling applications. Many of the lasers developed within the directorate are now finding useful applications in industry, including environmental applications, optical communications, medical diagnostics and surgical applications, and laser materials processing.

Background

Directorate researchers at Kirtland AFB, New Mexico developed COIL technology in 1977. This high-power laser is useful for applications requiring the delivery of a substantial amount of energy to a very small focused laser spot. The COIL is a member of the class of high-power lasers useful for industrial applications, including the materials processing tasks of high-speed cutting and drilling. These unique abilities make it an ideal candidate for nuclear reactor decommissioning, nuclear warhead dismantlement, disaster cleanup, and survivor rescue. It is also being studied by the oil and gas industry for well drilling. Any commercial or industrial application that requires very rapid, precise, and noninvasive cutting or drilling could be readily accomplished with a COIL. Because of the substantial power levels available with a COIL, the laser could also be used for broad area applications such as paint stripping, metal cutting, hole drilling, high-power fiber optic transmission, and rock crushing. COIL is a near-infrared laser with one of the best wavelengths for transmission through fused silica optical fibers. COIL is a low-pressure, flowing gas laser with an optical quality nearly diffraction limited. It is scalable for powers up to 40 kW and can be readily scaled to a power necessary to meet any very high-power industrial laser needs. Chemicals used in a COIL are all commonly found in heavy industry with well-known, understood, and safe handling techniques. The by-products of the COIL lasing operation are salt, water, and oxygen. There are, also, no greenhouse effect gases.

Self-Optimizing Software System Provides Way to Manage Data

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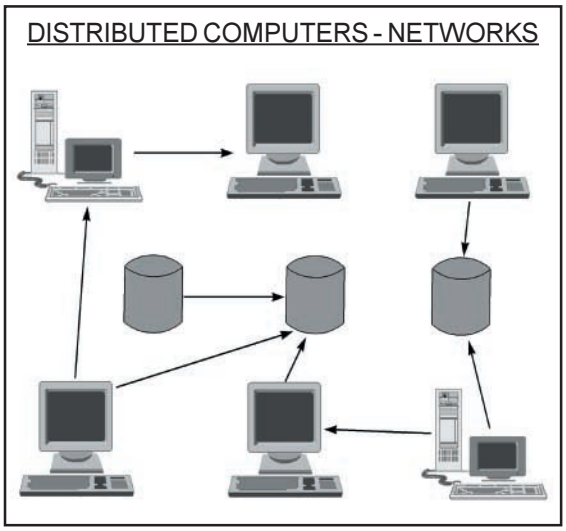


Payoff

Possessing a self-optimizing software system capable of intelligent query processing provides the Air Force and any information resource owner or design engineer an efficient way to manage multiple sources of data, continuously translating information into a new format. This capability not only saves time, but also provides more efficient configuration management without relying solely on experts.

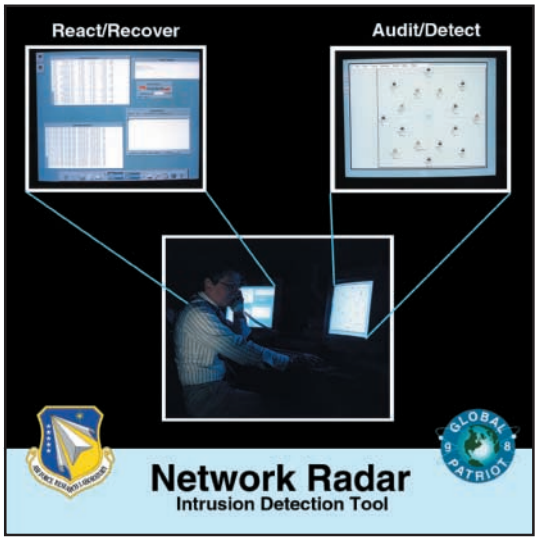
Accomplishment

Researchers from the Information Directorate and the Georgia Institute of Technology College of Computing, under a program funded by the Defense Advanced Research Projects Agency (DARPA), developed a software technique for integrating databases and knowledge bases. This heterogeneous information process of engineering designs (HIPED) utilizes intelligent query processing to provide the Air Force with more efficient configuration management in legacy systems, as well as offer expanded design capability.

Background

As the 21st century approaches, the Air Force realizes the need for a competent software management capability, in lieu of redesigning, reinvesting in, or disposing of the investment in various information resources. This information management challenge and the awareness of a shortage of specific new sciences developed for software, motivated DARPA to begin the I3 program. As one of the I3 programs, the HIPED program's main objective was the development of an approach for supporting large-scale engineering design activities that need access to heterogeneous database sources. HIPED is different from previous software developed for information management due to technology that not only supports database information or knowledge-base information, but also spans across both, integrating the support options offered to the users. In support of the main objective, designers of HIPED recognized two specific needs: supporting facilities for accessing heterogeneous data as well as knowledge sources, and using this program as a vehicle for research in the development of large-scale, high-performance, knowledge-based systems. To support both needs, HIPED researchers designed a software mediator, which provides a uniform access method and view of any database/knowledge-base system regardless of the design of the individual information system. The mediator also provides metadata query facilities, allowing the design system to determine relevant information to support queries and retrieve the actual data regardless of its location. In addition to its capabilities for facility support, the mediator provides intelligent processing capability (with an on-line explanation) to heterogeneous knowledge-base systems and knowledge compilation of query answers.

New Software Detects and Terminates Unwanted Computer Network Intrusions



Payoff

"Rome Says No!!" When those words flash on the computer screen, an unwanted computer intruder is detected and disconnected from further access. This new technology, called *Network Radar,* allows system administrators to track, in real-time, any apparent suspicious activity on a network, in a window on a PC/laptop screen. System administrators can then isolate and check the activity (such as individual keystrokes) of the suspected intruder and determine immediately if the intrusion is malicious. Within a matter of seconds after an attack is recognized, the administrator can go immediately to another window and shut down the intruder.

Accomplishment

This new software tool was developed by the Information Directorate's Defensive Information Warfare Branch through a contract with NetSQuared. This Beta version, written under the Small Business Innovation Research program, will deliver an intrusion detection/protection software package for both military and civilian users. The software is loaded onto a Unix workstation, which is then connected via a hub onto a server or router. The system saves computer attacks so they can be replayed and analyzed at a later date. This technology has dual-use application because it can monitor and protect any network, military or civilian, mobile or fixed.

Background

Air Force computer system administrators need to track, in real-time, any apparent suspicious activity on a network, in a window on a PC/laptop computer. To accomplish this task, the directorate contracted with NetSQuared to develop a new software tool called *Network Radar*. The directorate demonstrated this software at Global Patriot '98 (GP98), an Air National Guard exercise designed to train units to fight in a joint system environment. They loaded the Beta version of *Network Radar* onto a Sun workstation taken to GP98 for the initial demonstration. It was connected through a hub to the GP98 network in a non-interfering, monitoring mode in the Air Operations Center at Shaw AFB, South Carolina. The *Network Radar* window showed only authorized users who were using authorized ports and performing authorized business, such as scheduling bombing and refueling missions. To check "hostile" activity, the exercise red team attempted probing and penetrating the network, while placing malicious code and denying service to the systems connected to the network. *Network Radar* detected all this activity and allowed the operator to terminate the red team by sending a reset packet to hang up their terminals and flash the "Rome Says No !!" message on their screens.

ENHANCED ALL-SOURCE FUSION

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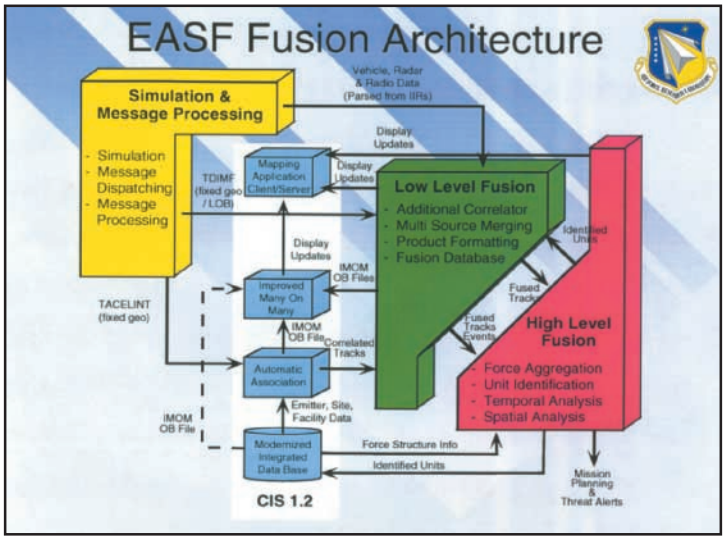


PAYOFF

Development of "patriotic" fusion has the capability to locate, identify, and track red, white (actually gray), and blue components of the electronic environment. This technology, called the Enhanced All Source Fusion (EASF) Advanced Technology Demonstration, functions within the Theater Battle Management Core Systems Combat Intelligence System architecture.

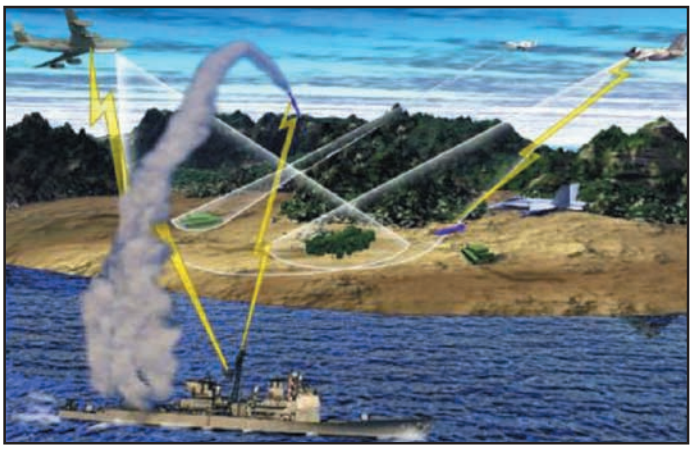
ACCOMPLISHMENT

The Information Directorate contracted with Sterling Software's Information Technology Division and Raytheon E-Systems to integrate existing software modules and some newly developed software that will provide the overall EASF System with data fusion capabilities. Data fusion, as defined by the Joint Directors of Laboratories Technology Panel on Command, Control, and Communications for Data Fusion, is "information processing that deals with the association, correlation, and combination of data and information from single and multiple sources to achieve refined position and identify estimation, and complete timely assessments of situations and threats and their significance in the context of mission operations." Continuous refinement of estimates and assessments, and evaluation of the need for additional sources or modification characterizes this. Directorate personnel demonstrated the EASF System to Air Force Special Operations Command (AFSOC), Electronic Systems Command, and Special Operations Forces personnel. Examples of data fusion functionality that currently do not exist operationally include the ability to combine outputs from multiple fusion engines, the ability to identify military units (as opposed to single military objects), and the ability to perform threat prediction/alerting.

BACKGROUND

The data fusion capabilities integrated and developed during the EASF effort provided AFSOC an innovative computer-aided capability to determine situation awareness and threat assessment to support mission planning, execution, and rehearsal. The approach used for the EASF effort integrated existing data fusion research and development applications to support AFSOC all-source data fusion requirements, by providing continuous near-real-time combat. AFSOC participation during the entire effort - from requirements reviews, interim spiral development demonstration, and scenario development to the final demonstration - ensured a product geared to enhance AFSOC capabilities.

AFRL and DARPA Advance Moving Surface Target Technology



Payoff

The Information Directorate and the Defense Advanced Research Projects Agency (DARPA) Special Projects Office, through the Affordable Moving Surface Target Engagement (AMSTE) program, are targeting enemy tanks, small boats, and tactical ballistic missile transporters. Entering the second phase of research, the AMSTE program, funded by DARPA, is investigating and developing technologies to affordably engage moving surface targets.

Accomplishment

Scientists and engineers from the directorate's Information and Intelligence Exploitation Division explored technologies in the initial phase of AMSTE that would tightly network ground moving target indication (GMTI) sensors to provide fire control quality tracks of sufficient accuracy and direct inexpensive munitions against moving surface targets. The second phase of this program, AMSTE II, will consist of a series of experiments that investigates critical technologies, explores performance boundaries, and demonstrates potential operational utility. The research will focus on developing a new capability for the services to strike with precision, moving surface threats from long ranges and in all weather conditions. The program will focus on GMTI radar, a sensor that detects moving surface vehicles from long distances. The next phase of the program will feature airborne experimentation and will demonstrate precision fire control and weapon delivery with limited target association challenges. The FY02 experiment will feature airborne experimentation and will demonstrate integrated highly reliable track maintenance and precision fire control. Finally, the FY03 experiment will be an end-to-end demonstration of AMSTE engagement capabilities.

Background

Moving ground targets pose a significant challenge to current weapon systems because of their dynamics. Idle vehicles can accelerate to speeds of 60 miles per hour in less than 10 seconds and stop in shorter periods of time. While typical military vehicles do not tend to accelerate or stop that fast, they still pose a significant challenge in maintaining accurate tracks. Vehicles also tend to mix with other vehicles, travel within groups or convoys, start and stop often, and use terrain to block their detection. Several initial studies conducted over the past year investigated the feasibility of precision engagement of moving ground targets using advanced sensor systems. The results of these studies concluded that, while obtaining the high accuracy required for precision fire control is possible, the real challenge is maintaining the track of the target during the battle management process. Over the next several years, directorate engineers will use technology in development to enhance the capability to strike moving targets with high accuracy.

Computed Tomography Helps Develop Composite Heat Exchangers

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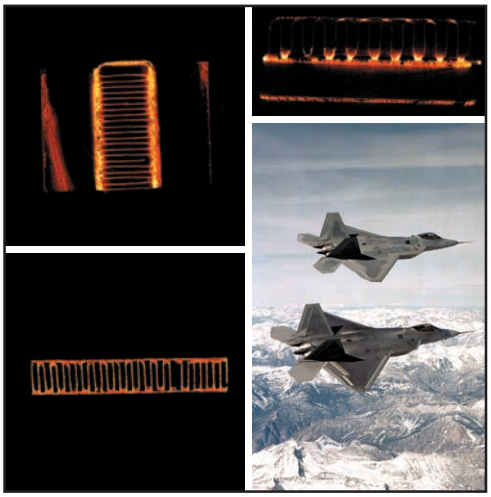


Payoff

Computed tomography (CT), provided by the Materials and Manufacturing Directorate (ML), offered the Air Vehicles Directorate (VA) an efficient, very effective means of comprehensive internal examination of prototype heat exchanger components for multi-service aircraft applications. A critical element of this examination was the capability to assess the interiors of these parts *in situ*, prior to being cut apart for other tests. By saving substantial time and effort in prototype evaluation, CT nondestructive evaluation of these components improved their development rate by a factor of two.

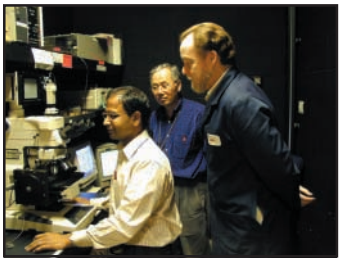
Accomplishment

High-temperature, low-weight, compact, carbon-carbon (C-C) composite heat exchangers for existing and next generation combat aircraft are under design and development by VA. ML provided CT to solve the critical problems of viewing and analyzing the internal structure of these heat exchangers during prototype development.

Background

Heat exchangers are a critical part of Air Force and other Department of Defense weapon systems, providing thermal management for on-aircraft environmental control systems. Since heat exchangers typically make up nearly half the weight of these systems, saving weight can materially add to the mission capability of combat aircraft. A program sponsored by VA is underway to develop a rugged, lightweight, high-temperature C-C composite heat exchanger for next-generation and existing thermal management systems. Two different assembly methods are under consideration. Conventional processing involves making C-C plates and fins, then brazing all joints to form the core, a method similar to making metal heat exchangers. Integral processing involves co-processing C-C fins and plates, then joining these structures by brazing. In either case, the joint bond is the most critical part of the construction. VA engineers evaluated both of these processes to determine the percentage and quality of braze bonding. The engineers performed many examinations and tests on the composite heat exchangers to determine the quality of the process and performance specifications for the resulting part. Examining the internal structures of the test parts normally required its destruction. Only CT, a nondestructive evaluation (NDE) test method, offers the capability to examine the internal structure of a test part as it will actually appear in use, and reveal invaluable data about the internal structures of the part under investigation. CT was also selected to study the quality control of the heat exchanger manufacturing process, thereby indicating whether the process could reduce risk to an acceptable level to establish a possible manufacturing technology program. VA selected ML's X-Ray Computed Tomography Facility to conduct NDE investigations. The first prototype coupon revealed that only minimal braze bonding had occurred, with an estimate of 20% fill. A second prototype coupon was fabricated and CT examination showed an estimated 80% braze bonding, a significant improvement in the manufacturing process. Analysis of a prototype coupon, prepared using the integral processing assembly, revealed a complete carbon bond between corrugation fins and the plate prior to brazing, as well as the level of the silicon carbide coating layer.

Portable Load Frame Examines Composite Materials



Payoff

By allowing researchers to identify and better understand the primary properties of composite materials, particularly textile composites and carbon foam used to build aircraft and space vehicles, the load frame test fixture facilitates design and development of ultra-stiff, ultra-lightweight structural materials benefiting national defense and commercial industry. Continued application of the test device could eventually lead to critical improvements in aerospace composite materials.

Accomplishment

Researchers at the Materials and Manufacturing Directorate successfully designed and fabricated a portable load frame for observing and recording *in situ* damage development in composite materials. The device measures the tensile load on a specimen using a load cell connected to a digital indicator as load is increased incrementally with a gas pressure regulator. The strains are recorded at each increment, as the edges of the specimen are simultaneously observed through a microscope for damage, and photographed with a camera. The images are stored digitally for later retrieval. In many advanced composites, cracks, due to process-induced residual stresses, close upon specimen unloading. Thus, traditional test techniques of damage characterization after specimen unloading fail to identify the damage initiation process in advanced composites. The *in situ* observation of specimen surface, while loaded, allows researchers to identify and better understand damage and failure mechanisms of advanced materials systems. It also helps develop accurate design allowables for ultra-stiff, ultra-lightweight structural materials used in supporting military and commercial applications. Expanded application of the test methodology and information gained from the testing could lead to substantial savings in structural design.

Background

Fiber-reinforced composites technology has matured in the past three decades. Nevertheless, the continued growth of composite applications, both in the defense and commercial sectors, inevitably lies in the development of low-cost manufacturing processes for these materials. Use of fiber preforms proved to be highly effective in providing low-cost composite parts. This is especially true for complex geometry and contoured parts, which are difficult to make from unidirectional composites. Woven and braided (textile) composites are, consequently, widely used in the production of structural composite parts for aircraft and space vehicles, where strength and weight are serious considerations and manufacturing costs are of major importance. To use these composites efficiently in structures, a need to develop a clearer understanding of failure mechanisms of these materials in the presence of extensive residual stresses remains. Materials scientists and engineers at the Structural Materials Branch designed and fabricated a portable load frame for observing and recording *in situ* damage development in materials while the specimen is loaded. This unique device accurately measures tensile load on a specimen using a load cell connected to a digital indicator. The load frame is designed to generate a maximum load of 2,000 lbs using a gas pressure of 6.35×10^5 Pascal (100 Psi). The test fixture was designed and developed by Dr. Ran Y. Kim and John Camping of the University of Dayton Research Institute and Dr. Ajit K. Roy, a materials research scientist in the directorate.

Multi-Junction Design Improves Spacecraft Solar Cells

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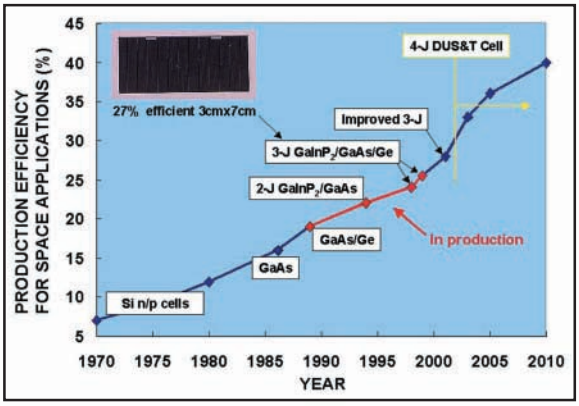


Payoff

The Manufacturing Technology (ManTech) program for multi-bandgap solar cells resulted in increased payload mass, reduced cost, and complete market penetration of multi-junction solar cell technology. As the result of this program, the US is world-dominant in high-performance solar cell technology for space. The 35-40% solar cell design by the Space Vehicles Directorate (VS) promises to further reduce solar array size, mass, and cost. The project will also result in lower consumer cost for telecommunications, Internet, television broadcast, and other services, allowing US industry to be more competitive in the global marketplace.

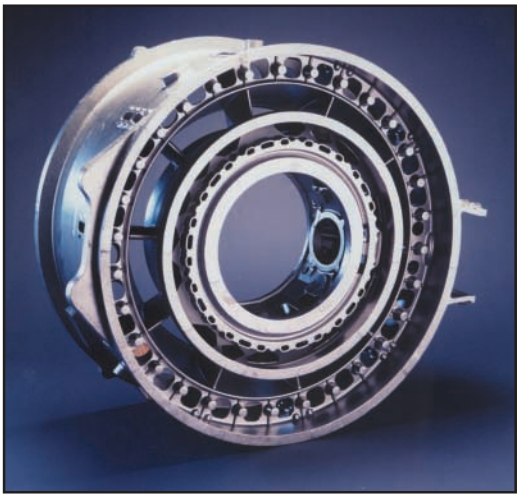
Accomplishment

Under a contract with the Materials and Manufacturing Directorate (ML) and the technical direction of VS's Space Technology Integration and Demonstration Division, TECSTAR, Inc. and SpectroLab, Inc. developed solar cells for space vehicles that will increase available power by 35%, while reducing the cost per watt by 15-20%. The multi-junction space solar cells convert a larger portion of the solar spectrum into electricity than previous designs, with solar to electric conversion efficiencies of 25%.

Background

High-performance solar cells must provide added power for space missions without increasing solar array size or weight. Previously, multi-junction solar cells were laboratory curiosities, too expensive for general use. The goal of this program, managed by ML's ManTech Division and VS's Space Technology Integration and Demonstration Division, was to decrease the cost of solar cells so they could be used beneficially on operational spacecraft. Funded by ManTech, VS, the Space and Missile System Center, and the National Aeronautics and Space Administration, the cooperative program grew out of the experience and expertise developed over 15 years of high-efficiency solar cell development. Previous state-of-the-practice space solar cells were single-junction gallium arsenide with efficiencies of 18.5%. Multi-junction solar cells for spacecraft applications became the industry standard as a result of this program. Unlike previous programs for single-junction cells, the multi-junction program limited the production cost increase to 15% per solar cell. When combined with the 35% increase in cell efficiency, the results were a 15% cost reduction per solar cell watt. Spectrolab, Inc. of Sylmar, California, and TECSTAR, Inc. of City of Industry, California, sought to develop and market the most advanced, cost-effective solar cell technology for the next generation of spacecraft. Today, both companies commercially offer the three-junction solar cells with efficiencies of 24.5-25%. The new multi-junction cells reduce solar array size and mass, enabling increased power and mass for the payload. This technology is now available to all domestic spacecraft prime contractors for use in both commercial and government programs. This technology, allows more capable spacecraft to be built around existing buses and launched on existing boosters, which benefits the US government space programs. Researchers expect use of this technology in almost all military spacecraft within the next few years, and launch of at least a dozen military spacecraft that use these solar cells within the next five years.

Process Improvements Help Lower Costs



Payoff

The Engine Supplier Base Initiative (ESBI) program is helping lower production costs of aircraft gas turbine engines. The identification and implementation of new manufacturing processes will help stretch dwindling acquisition dollars for Air Force systems. Cost and cycle-time reductions already achieved through ESBI prove the value of seeking process improvements. As a result of these successes, the ESBI effort initiated 65 separate technical activities at 12 Howmet Corporation and Precision Castparts Corporation (PCC) sites.

Accomplishment

Under a cooperative agreement with the Materials and Manufacturing Directorate, PCC and Howmet are helping lower the production costs associated with manufacturing aircraft gas turbine engines. Identifying and implementing manufacturing technologies will streamline the production of cast airfoil and structural components used on those engines. These efforts will help save the Air Force substantial dollars in overall acquisition costs, improve the industrial base, and enhance competitiveness in the gas turbine engine industry.

Background

Gas turbine engines used on many of today's Air Force and commercial aircraft make up a significant cost factor in the total cost of the aircraft. Lowering production costs of the engines and, therefore, lowering the overall cost of aircraft will help save the Air Force precious acquisition dollars. This is the objective of the ESBI, sponsored by the directorate's Manufacturing Technology Division through a cooperative agreement with PCC of Cleveland, Ohio, and Howmet Corporation of Whitehall, Michigan. Four recent successes by PCC offer strong evidence that the ESBI program is significantly shortening the time to implement Air Force-sponsored manufacturing technology improvements. One project involved replacing the old waxes used to make patterns for castings with newer waxes to improve the dimensional stability, pattern surface quality, and dewaxabililty of molds. The project reduced the number of waxes required from five to three by balancing the requirements for characteristics needed for various parts. Another successful effort was the Finishing Reduction Process project for the final machining of ceramic cores used on airfoil castings. Under this project, computerized numerical control (CNC) replaced labor-intensive and often inaccurate hand-finishing of the cores. This project extended CNC to finish most of the core. It accomplished two primary objectives demonstrating that CNC techniques were capable of reducing finishing labor by 50%, while significantly improving dimensional accuracy on critical features. Yet another success under ESBI was the Mold Improvement project. This project focused on the mold-making operation which impacts surface quality of castings and also influences product yield and repair costs of castings. Finally, PCC developed a new shell system that will significantly reduce the amount of rework required for large structural turbine engine castings, such as turbine rear and spoke frames, diffusers, tangential on-board injectors, and combustor cases. Rework associated with the weld repair of defects in the casting accounts for as much as one-third of the price of a structural casting. These defects are often due to the presence of ceramic shell flakes that erode into the molten metal during pouring and also to microporosity associated with solidification.

Advances in RFC Inspection Technology Increase Operational Readiness

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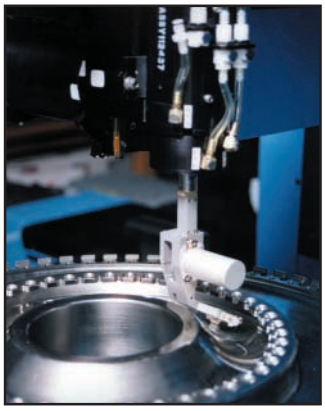


Payoff

With relatively small expenditures, the upgrades achieved for the retirement for cause (RFC) engine structural integrity program (ESIP) make it possible for Oklahoma City Air Logistic Center (ALC) to continue supporting programs for inspection-based life management of fracture-critical engine components. The RFC system is the only system today with the capability to run different original equipment manufacturers' engines. These RFC systems with advanced capabilities will help save critical materials and minimize requirements for spares, permitting the Air Force to more effectively meet its mission capability requirements. In turn, operational readiness of critical engine components to complete weapon system mission capability requirements is improved.

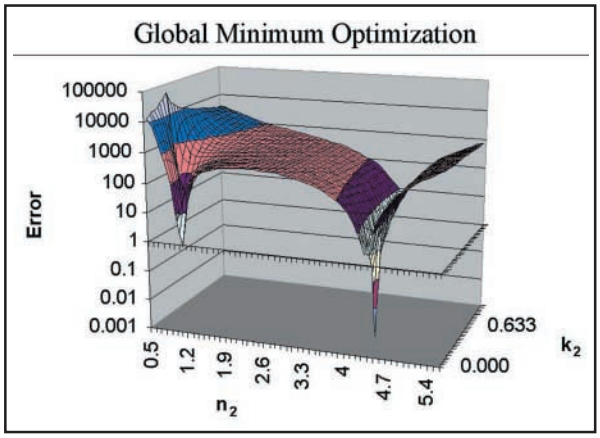
Accomplishment

The Materials and Manufacturing Directorate, with a contractor team from industry and academia, developed and implemented advanced inspection technology for fracture-critical turbine engine components. The comprehensive package of advanced technology tools developed to improve the RFC inspection system will achieve significant savings in engine maintenance costs, and increase the operational readiness of high-performance engine components needed for mission accomplishment.

Background

Fracture-critical rotating components of high-performance gas turbine engines for Air Force weapon systems consist of exotic alloys that are often complex and require extensive machining. Damage tolerance analysis (DTA), a major concept for managing the life of these disk components, assumes that damage (a flaw of minimum detectable size) is present at all critical locations within any disk. Inspection-based life management for Air Force engines, such as the F-100 and F-110 engine series that power Air Combat Command F-15 and F-16 fighter aircraft, use the DTA concept. The ESIP embodies the DTA life management approach and implements engine component inspection via the RFC component inspection system. These programs ensure that flaws in fracture-critical components will not grow to critical size through two inspection intervals. They demand a rigorous assessment of the capabilities of nondestructive evaluation, since RFC inspections can decisively impact weapon system mission readiness. Originally, engine components at the San Antonio and Oklahoma City ALCs were evaluated using RFC ESIP systems. Over the past 12 years, these systems amassed aggregate savings of six million pounds of critical materials, plus $1 billion in overhaul costs. Engine availability increased significantly while the need for spares decreased. The ratio of return on investment (ROI) amounted to 25 to 1. However, the increasingly complex disks in newer supersonic turbine engines, such as the advanced -229, -129 and -220 versions of the F-100 and F-110 engines, stretched original RFC ESIP inspection technology to its limits. A program, initiated to upgrade the hardware and software used in RFC ESIP inspection technology, provided the capability to meet the challenges of the 21st century. Directorate researchers from the Nondestructive Evaluation Branch led this program and engineers from Veridian Engineering of Dayton, Ohio; American Robot Corporation of Oakdale, Pennsylvania; Uniwest of Pasco, Washington; the University of Dayton Research Institute of Dayton, Ohio; and Southwest Research Institute of San Antonio, Texas, carried out the program. Researchers expect this newly upgraded RFC ESIP system to generate a 10 to 1 ROI in the next two years.

Adaptive Process Control Technology Improves Quality and Reduces Costs of Semiconductor Materials



Payoff

Technology, developed for the integrated use of neural networks and genetic algorithms, will aid real-time process control in producing semiconductor materials and reduce development and production costs of advanced semiconductor materials for Air Force threat and detection applications. In addition, this process control technology affords the novel architecture and unique capabilities to demonstrate applications in real-time fault detection of Internet data communication routes. Because of the Internet application and the market size, AIWare, Inc. is discussing the sale of this technology to Computer Associates, Inc. who would market it for those applications.

Accomplishment

Under a contract with the Materials and Manufacturing Directorate, AIWare, Inc. of Cleveland, Ohio, developed a real-time monitoring system that improves the quality of semiconductor materials used in Air Force defensive radar systems while reducing their production costs. This process control system automatically adjusts the manufacturing process to affect the desired thickness and chemical makeup of multi-layer semiconductor materials. Based upon a unique coupling of sensors and genetic algorithms, the control system also demonstrated applications in real-time fault detection on Internet data communication routes.

Background

Building quality into an advanced semiconductor material requires process control as one of the key elements. Built-in quality reduces inspection, as well as rework and scrap costs, while increasing yield in lower overall acquisition costs. Limits on the control of advanced semiconductor processes to date are due to deposition processes for advanced semiconductors that exceed the limits of conventional control technology, more specifically the time between detection and corrective action. The prototype system devised in this Small Business Innovation Research contract with AIWare, Inc., overcomes the response time limitations of conventional approaches. The basis for the system adaptivity is a unique coupling of neural networks and genetic algorithms that distinguish process information from background noise for precise control of material thicknesses, within three atomic layers (or 10 angstroms). Using a genetic algorithm to continually search and denote the process trajectory, the control system can precisely predict material thicknesses a few steps into the future, which allows for automatic in-process thickness control. Relating to material processing, time constants which sometimes preclude real-time control limit detection of communication faults and subsequent corrective actions. However, the coupling of neural networks and genetic algorithms is useful to capture the process trajectory of a fault. Upon learning a trajectory pattern, applying corrective actions in real-time, in some cases, can alleviate the fault altogether or at a point where it can be resolved with minimal or no performance degradation or cost.

Neural Network Model Improves Accuracy and Reduces Scrap for Machine-Tooled Parts

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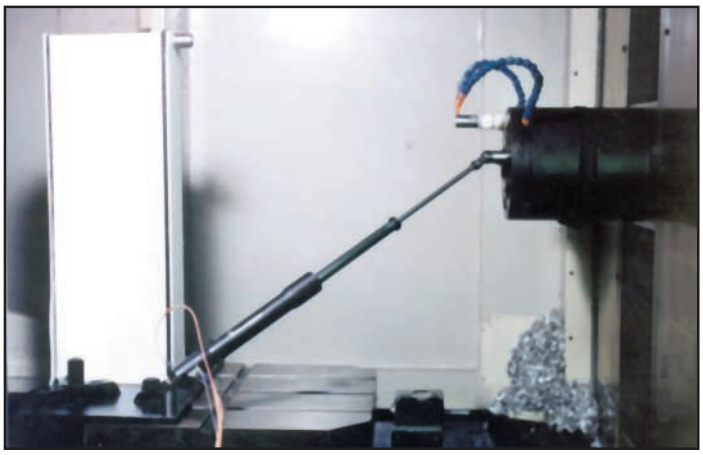


Payoff

This Manufacturing Technology (ManTech) project developed a robust, cost-effective method to position cutting tools with absolute positioning accuracy. This system provides the improved machine tool accuracy to improve quality control, reduce scrap, and save potentially millions of dollars through acquisition cost avoidance. In a hypothetical case study of a military gas turbine engine, where cost savings of improved machining accuracy is the reduction of scrapped raw material during the production process and where the value of the raw materials accounts for half of this cost, elimination of 3.5% of the scrap rate would decrease the overall cost by $70,000 for a $4 million engine. For a typical production run of 600 engines, the result is a $42 million cost avoidance.

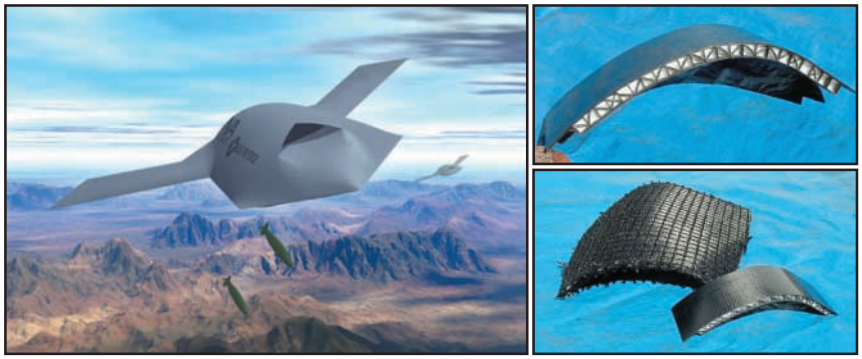
Accomplishment

Under a contract with the Materials and Manufacturing Directorate, Tetra Precision Incorporated of Gainesville, Florida, developed a system that improves the accuracy of parts machine tooled for aircraft components. Using a calibration device in conjunction with sensors, this system builds a model that provides absolute positioning accuracy for the cutting tool. Incorporating the model into a commercial machine tool could improve quality control, reduce scrap, and save millions of dollars through acquisition cost avoidance.

Background

Manufacture of metal parts require machine tools to cut away excess metal and form the parts. When processing parts for aircraft engines, error tolerances are minute with constant pressure on industrial manufacturers to produce high quality products while maintaining high productivity. Ninety percent of the cost of ensuring quality is due to scrapping or reworking of parts that do not lie within design tolerances, thus adding to the cost of the part. Recently, development of methods to aid in accurate production of products the first time manufactured was emphasized. These methods must provide the correct compensatory actions to the machine tools by actively monitoring the error sources of machining processes rather than passively inspecting machined parts. The directorate's ManTech Division, under a contract with Tetra Precision, Inc., adopted a direct workspace identification technique using a new calibration device called the Laser Ball Bar to directly measure the total error at the cutting tool. This device, used in conjunction with a neural network, will rapidly build a model of the machine tool for a thermal duty cycle that simulates machining of large workpieces. The system makes uses the self-learning properties of artificial neural networks to predict the net positioning error at an arbitrary point in the workspace, from knowledge of the error at some specified points in the workspace. The measurement of geometric errors and their thermal variations, as well as correlation with other process variables, provide this knowledge.

Lightweight Core Adds Strength and Savings to Fuselages and Substructures



Payoff

TYCOR's™ affordable and lightweight core, coupled with enhanced shear and compression properties, make it an attractive solution for fuselage and substructure components. The ability to resist catastrophic failure and fail in a "ductile" manner allows TYCOR™ to continue to carry a significant load after the initial failure and exhibit large deflection before final failure. The progressive and stable failure mechanisms resembling metal plasticity are extremely desirable for structural safety. The core materials are suitable to replace traditional core materials in a diverse range of product applications in transportation, construction and infrastructure, and aerospace and defense.

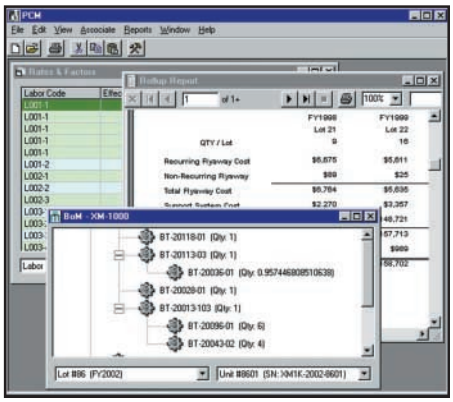
Accomplishment

A unique partnership between the Materials and Manufacturing Directorate (ML), the Air Vehicles Directorate (VA), and the Munitions Directorate led to the successful development and transition of a dynamic structural sandwich material which is stronger and more cost effective than traditional core materials. WebCore Technologies, Inc. pioneered the new core structure during Phase I of a Small Business Technology Transfer effort with ML. Further refinement of TYCOR™ took place during Phase II STTR and Phase I Small Business Innovation Research efforts funded by the three directorates and managed by VA. Current evaluation of TYCOR™ for possible use in the Unmanned Combat Air Vehicle and the Joint Air-to-Surface Standoff Missile programs could lead to substantial savings in fuselage costs and improvements in structural reliability.

Background

TYCOR™ cores offer superior structural performance, durability, weight savings, and cost savings compared to traditional foam core materials, as well as a high degree of design flexibility using different types of foam, fibers, and fabrics. WebCore's unique process integrates porous fiberglass or carbon-fiber reinforcements in a three-dimensional truss architecture using the thickness of low-cost, low-density foam to achieve z-directional reinforcement. Design of TYCOR's™ fiber-reinforced-foam core materials includes use in liquid molding processes where the porous reinforcements act as resin channels during molding, then co-cure with the skin layers to produce an integrated sandwich panel with improved structural performance. The dry fibers, infused with resin during molding, cure to form the structural members. The skin attachment feature greatly enhances the core-to-skin bonds in the sandwich panel, resulting in high strength and excellent damage tolerance capability. In addition, the fibers that compose the reinforcing members are mechanically tied with the sandwich panel skins to eliminate skin-to-core delamination. Current prototype machinery can manufacture TYCOR™ cores and preforms in thicknesses ranging from one-quarter to three inches. Depending on the design variables and choice of materials, the core's density in the molded panel ranges from about 6 to 18 lbs per cubic foot. The core shear strength ranges from about 150 to 750 lbs per square inch (psi) and the core shear modulus ranges from about 5,000 to 50,000 psi. The compressive strength ranges from approximately 300 to 1,200 psi. Carbon fiber reinforced TYCOR™ panels show excellent fatigue resistance, offering 100% strength retention under cyclic flexural loading after one million load cycles at 50% of maximum static load. TYCOR™ cores and sandwich panels also exhibit outstanding impact damage tolerance capability. Upon impact, the panels developed visible impact damage on the frontal face but no damage on the opposite face.

Production Cost Model Offers Unique Cost Management Capability



Payoff

The Production Cost Model (PCM) delivers the ability to model the cost of a production program, while avoiding up to 75% of the time and cost normally required to build a program-specific, detailed PCM. The PCM's level of detail provides insight into the program's cost drivers and supports critical management decisions. The flexibility of the PCM allows it to cover all program costs normally included in the production budget, as well as program transitions from the development phase into production, and from production into the operations and support phase. Major weapon system programs, modifications, and updates, which used an earlier version of PCM, experienced recurring cost savings in the 15 to 25% range. With PCM's added features, elimination of more recurring costs earlier in the program, can compound the savings.

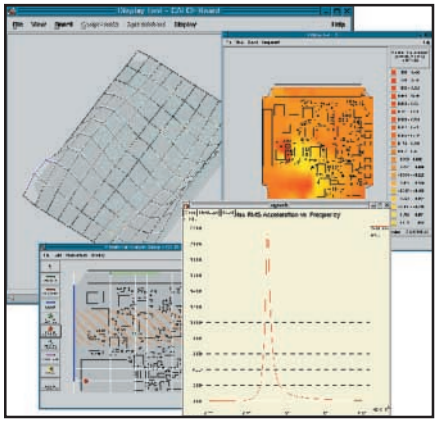
Accomplishment

Under a contract with the Materials and Manufacturing Directorate, Wallace and Company developed a generic PCM for Air Force weapon systems that can be tailored for use on various commercial contractor production and cost accounting systems. Developed under a Small Business Innovation Research project, PCM eliminates the need to develop contractor-specific programs, and provides critical support for management decisions on the production of a hardware system at a fraction of the time and cost of current models.

Background

Weapon system programs must estimate the cost of each phase of the acquisition process. A variety of management purposes, from day-to-day execution of the program to long-range budgeting and program approval decisions must use these cost estimates. While a number of parametric models are available for use in the early conceptual and developmental stages of the acquisition process, no generic cost models with a high degree of reliability and validity that are adapted for use in the production phase of a given program, existed until now. To accurately model the cost of a production program, program specific data, such as the work content and bill of materials, must be considered. The added long-term benefit in a model with this level of detail is supporting the reduction of recurring manufacturing cost through identifying and managing cost drivers. However, few programs attempt to build such a model due to the time and expense required. To build and validate such a model for a large, major defense program, experience shows two or more years and a multi-million dollar investment are required. PCM fills this void and provides an adaptable generic tool to accommodate the unique aspects of any production, modification, or update program. A bill of material and a common work breakdown structure tree is the basis for the model. The work breakdown structure templates provided with the model may be used in their current format or adapted to the structure of any given program. The bill of material may be loaded electronically or constructed manually and linked to the appropriate nodes in the work breakdown structure. A parts master that contains the factual and historical information about each part needed in order to determine its historical cost and project future estimates is at the core of a bill of material-based system. A unique feature of the PCM is its flexibility to address all types of costs that are normally part of a production program. In addition to the recurring labor and material cost of produced items, PCM offers the ability to track and forecast non-recurring costs, such as tooling and engineering, as well as the cost of support equipment, spare parts, and support planning tasks. This flexibility ideally suits the PCM for cost management during the transition of a program from the development phase into production and from production into the operations and support phase.

Physics of Failure Approach Radically Shifts Management of Sustainable Electronic Systems



Payoff

The Physics of Failure Approach to Sustainable Electronic Systems (PASES) program promises to establish the causes of failure during the design stage, thereby substantially lowering the life-cycle cost of an aircraft. Use of this knowledge designs out failure mechanisms and optimizes the support environment for the equipment. Application of the calcePWA software to electronic systems in avionics, automotive, computer, consumer, military, space, and telecommunication applications was successful.

Accomplishment

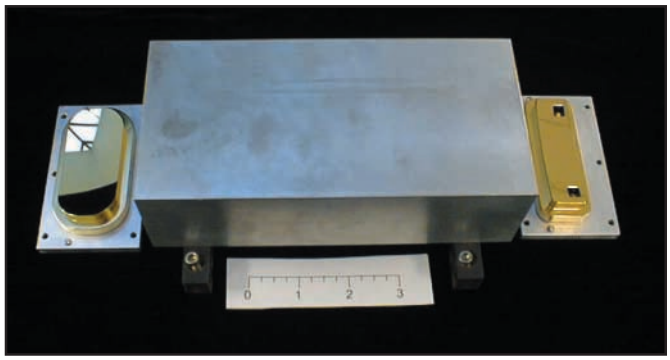
Under a contract with the Materials and Manufacturing Directorate, the University of Maryland (UM) initiated a program that substantially lowers aircraft life-cycle costs. The PASES program establishes the causes of failure during the design stage and changes the maintenance focus to a proactive approach of preventing failures.

Background

In 1994, the Department of Defense issued directives instructing officials to write procurement specifications in terms of performance requirements. In response to this directive, the military turned the responsibility of supporting military specifications over to suppliers for design and delivery of equipment to meet performance specifications. One of the most important of these performance specifications is equipment reliability. Traditionally equipment reliability was defined in terms of mean time between failure (MTBF). This measure is simply the number of equipment operating hours accrued by the fleet in a given time period divided by the number of failures that occurred during that same time period. While the sequence of MTBF numbers calculated over a long period is a useful historical record of the reliability of a piece of equipment, it does not provide mission and logistics planners with information on equipment longevity. That knowledge enables planners to forecast the times at which failure will occur and permits planned maintenance activities to avoid unscheduled maintenance activities. The idea of maintaining equipment only at scheduled times leads to the notion of a maintenance-free operating period (MFOP). This is a period of time during which a system is both operational and can carry out its required functions without maintenance activities and without encountering failures. The directorate's Manufacturing Technology Division is developing an approach to move from using MTBF to MFOP as a measure of reliability. Based on work done at the UM's Computer Aided Life Cycle Engineering (CALCE) Electronic Products and Systems Center, the PASES program is attempting to predict failure occurrence during the design cycle. This program focuses on the creation of systems for the defense industry that have lower life-cycle sustainment costs by instituting a cradle-to-grave physics of failure (PoF) program as an up-front, proactive and concurrent approach to achieve system reliability, manufacturability, technology and parts risk management and affordability. CalcePWA is a computer software provided free to Air Force contractors to work concurrently during the design process in order to facilitate proactive PoF design assessment of electronics. The software provides the capability to model most modern printed wiring assemblies and contains a state-of-the-art reliability assessment capability developed around product life-cycle analysis.

Advanced Infrared Sensor Improves Identification, Measurement, and Control of Air Emissions

16



Payoff

The advanced air emissions analyzer, unlike conventional devices, can analyze several gases simultaneously, speeding up identification and measurement. This device can improve environmental monitoring and control at bases throughout the Air Force. Successful demonstrations using two analyzer prototypes indicate that other military services and private industry could also use the technology to strengthen their environmental compliance efforts, resulting in a cleaner, safer environment.

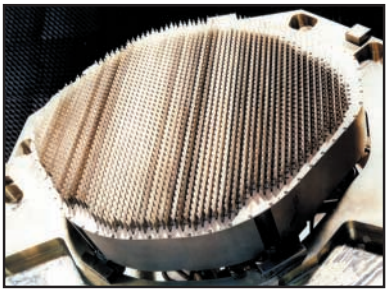
Accomplishment

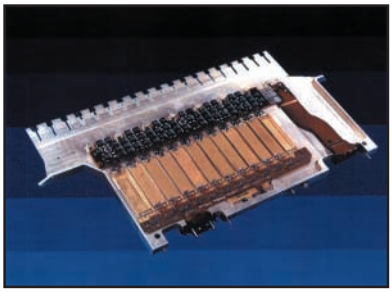
Advanced Fuel Research, Inc. (AFR), under a contract with the Materials and Manufacturing Directorate, developed an emissions analyzer to help control air pollution. The analyzer will provide the Air Force faster identification and measurement of emissions from aircraft engines, paint booths, vehicle exhaust systems, and other sources. The analyzer's state-of-the-art sensor and its capability to analyze several gases simultaneously impressed three corporations to place multiple orders.

Background

In 1996, the Air Force outlined a requirement for a technology that could accurately measure and characterize gaseous air emissions from such sources as jet engines, paint booth operations, and vehicle exhaust. Under a Small Business Innovation Research Phase I program, AFR responded by designing an advanced air emissions analyzer using a state-of-the-art infrared gas cell and a spectrometer. The Phase II effort expanded this technology through the design and delivery of two unique Fourier Transform-Infrared (FT-IR) gas cell prototypes to the Air Force. FT-IR technology uses an infrared beam that is absorbed by many gaseous substances in a characteristic manner. Analysis of the resulting absorption spectrum identifies and quantifies the substances present based on the spectral location and magnitude of the absorptions. One of the two Phase II FT-IR prototypes contained a small, fully integrated gas cell to make the unit portable. The other system used a rugged cell with special optics allowing operation in corrosive environments. Unlike conventional systems requiring an array of gas analyzers, the prototypes monitored and characterized multiple gas emissions simultaneously. Supported by the directorate's Airbase and Environmental Technology Division at Tyndall AFB, Florida, AFR conducted demonstrations at Arnold Engineering Development Center at Arnold AFB, Tennessee, and at Pratt & Whitney's facility in Connecticut. Following the demonstrations, several customers requested modifications to decrease the gas purge time, enabling more accurate engine emission readings. As a result, AFR initiated the development of a modified cell, which successfully demonstrated rapid response time and provided desired results for the customers. The directorate sent the analyzer to the Arnold Engineering Development Center for a two-month evaluation. Several companies monitored this evaluation, including Pratt & Whitney, General Electric, Allied Signal, Rolls Royce, Aerodyne, and Boeing, as well as the National Aeronautics and Space Administration, Seimens-Westinghouse, and Williams International. At least three expressed an interest in purchasing multiple units of the new system.

Improved Manufacturing Process Reduces Cost of F-22 Radar Components





Payoff

This Manufacturing Technology program automated the process for connecting the radio frequency, digital signals, and direct current electrical impulses between the components and manifolds that make up an F-22 radar antenna subarray. Replacing costly and labor-intensive flex circuit interconnects with automated ribbon bond interconnects resulted in a cost avoidance of $98,000 in material due to the elimination of flex circuits and $157,000 in first cycle and rework labor. During the planned production run of F-22 Raptors, a total cost avoidance of $60 to $87 million will result. The F-22 Program Office selected this interconnect process for production of F-22 radar systems.

Accomplishment

Under a contract with the Materials and Manufacturing Directorate, Northrop Grumman Corporation of Baltimore, Maryland, developed an improved manufacturing process for F-22 aircraft radar components that could result in a cost avoidance of nearly $87 million on the planned production run for the aircraft. By replacing thousands of costly and labor-intensive flex circuit interconnects on the radar's subarray components with improved automated ribbon bonds, the amount of hands-on labor and required rework was decreased, while the number of acceptable arrays per production run was increased.

Background

The F-22's APG-77 electronically scanned array antenna consists of several thousand transmit/receive modules, circulators, radiators, and manifolds assembled into subarrays and then integrated into a complete array. The baseline design, using thousands of hand-soldered flex circuit interconnects, made the numerous radio frequency, digital, and direct current connections between the components and manifolds that make up the subarray. Replacing the hand-soldered flex circuit interconnects with automated ribbon bond interconnects, vastly improved the first pass yield of the subarray assembly, while touch labor and rework were simultaneously reduced. The ribbon bonding process completely eliminates eight different part numbers associated with the flex circuits. Reprogramming the bonding process will respond to changes in subarray design. Northrop Grumman Corporation improved the ribbon bond interconnect process currently used in the assembly of radar circulators, and used a design based on experimental techniques to achieve reliable bonds on six different materials, at relatively low working temperatures. The fact that while ribbon bonds are typically formed at 160°C, the adhesive used to mount some components on the radar subarray can tolerate no more than 100°C, which drove the need for low-working temperatures scaling up the process allowing formation of all of the electrical interconnects of a relatively large assembly, such as the radar subarray, in one automated process. The new process allows the formation of reliable, repeatable ribbon bonds at low working temperatures, as well as their incorporation into an automated assembly work cell capable of assembling a full-size subarray in a production mode. This working cell includes the plasma cleaner for ribbon bonding along with robotics and reflow ovens for other F-22 subassembly fabrication. Before the process improvement, APG-77 radar subarrays averaged more than three defects requiring rework per subarray. The new interconnect process reduced the defects requiring rework to less than one defect per eight subarrays, and the simplified process for reworking a defective ribbon bond. The process capability for the interconnect process improved from .86 for the flex circuit to at least 1.33 for the ribbon bond interconnect.

Improved Stress Analysis Tools Trim Aircraft Composite Structure Acquisition Costs

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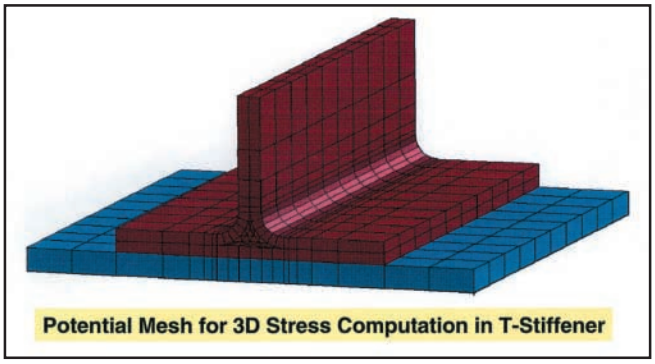


Potential Mesh for 3D Stress Computation in T-Stiffener

Payoff

The capability afforded by the ZIG-ZAG element allows accurate modeling and analysis of the more affordable three-dimensional (3-D) composite bonded joint concepts, and provides the analysis tools required to determine structural limit loads. Prior to this, the ability to efficiently predict the 3-D stress state in a complex composite structure did not exist. This technology is part of a toolbox of technologies necessary to reduce composite structure acquisition costs by half. Savings realized through lower costs could result in significant increases in the use of advanced composite materials in fighter aircraft and other weapons systems, while enhancing composite manufacturing processes, structural reliability, and flight safety.

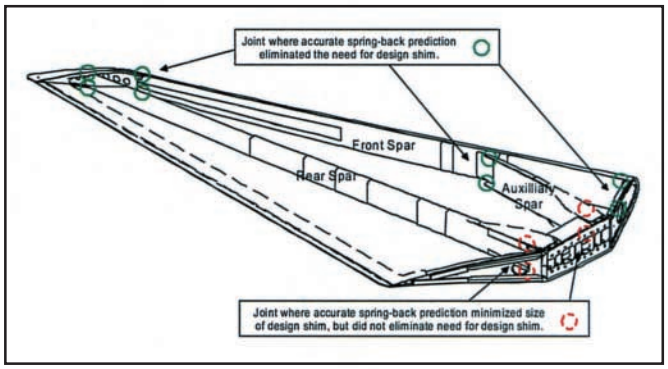
Accomplishment

A Materials and Manufacturing Directorate project identified a method for improving the analysis tools used to measure 3-D stress in aircraft component structures. Developed as part of the "Composites Affordability Initiative" (CAI), the approach uses finite element technology in the design process to assist in predicting the performance of innovative bonded composite structures. This approach, if successfully applied and coupled with other key technologies, will lead to a 50% reduction in fighter airframe acquisition costs.

Background

The costs of advanced composite primary structures for Department of Defense (DoD) applications generally range from $1,000-$2,000 per pound. The long-range goal of CAI reduces the acquisition costs of advanced composite structures to $100-$200 per pound. With more affordable structures, the use of composites on future DoD weapon systems should increase significantly. One way to enhance affordability is through the use of bonded and reinforced joints, which requires improved analysis tools for designing and certifying the joints. The existing analysis tool is one-dimensional and can predict the shear stress in the adhesive, but it ignores the peel stresses. Shortcomings currently exist in commercial finite element analysis codes when predicting the 3-D (interlaminar) stress state of 3-D composite structures. Hence, an improved tool is necessary, one that can handle complex 3-D geometry and recover the interlaminar stresses. Accurate prediction of the stress state is necessary to reliably predict failure of traditional laminated composites, as well as the more complex textiles through thickness reinforced-composites. Small brick element aspect ratio requirements do not accommodate efficient modeling of thin-layered structures. Therefore, brick elements with one-ply material per brick must accurately compute the interlaminar stress field, thus simplifying the modeling effort. Scientists and engineers supporting the tri-service/industry CAI effort, helped identify an existing finite element capability which, when coupled with a commercial code, can efficiently analyze the stress state of composite structures. The CAI team agreed that the existing ZIG-ZAG finite element technology, developed by Dr. Ron Averill of Michigan State University, offered the capability needed. This element is a layered brick, which offers higher-order kinematic behavior with "zig-zag" linear interpolation from layer to layer, aspect ratio insensitivity, and ease in bending behavior unlike most brick elements. The ZIG-ZAG element, designed to be a composite brick and specifically created for composite stress analysis, is fully compatible with commercial finite element software.

Eliminating Assembly Shims Lowers Cost of Performance-Improving Wing Tips



Payoff

Engineers designed the 767-400ER raked wing tip to use shimless assembly technology. During the initial production of the 767 wing tip, the goal of eliminating shimming requirements at the eight assembly joints was 100% successfull. Shimless assembly technology, applied to the 767 fleet and other commercial aircraft, could lead to significant savings. Shimless technology applied to Air Force systems could further reduce costs by supporting more effective design and manufacturing techniques, improved aerodynamics, increased fuel efficiency, and range.

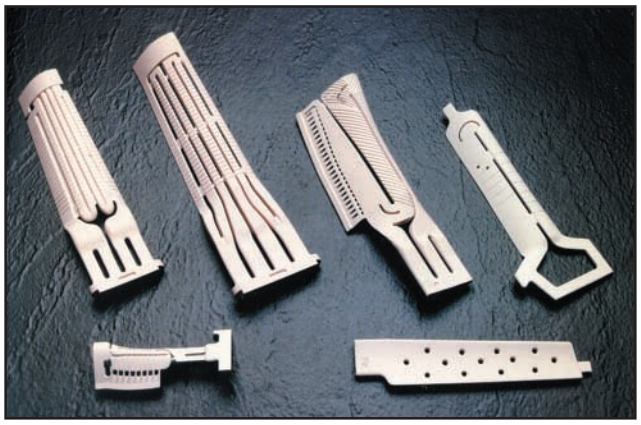
Accomplishment

Engineers at the Materials and Manufacturing Directorate, in conjunction with the Boeing Company and the University of British Columbia in Canada, successfully demonstrated the feasibility of eliminating all the shims required to assemble composite wing tips for the 767 aircraft, using advanced process modeling concepts. Under contract with the directorate, engineers at Boeing's Composite Manufacturing Center near Puyallup, Washington, supported by the university, eliminated the need for shimming at the eight assembly joints - a technological achievement that lowers wing tip assembly costs by four to five percent per aircraft. Raked back to enhance aerodynamic efficiency, the new wing tip design enhances flight performance and saves fuel. Reducing the wing tip assembly cost, even by a small amount, benefits commercial aviation and the Air Force.

Background

Assembly of aircraft structures requires the matching of a vast number of sub-components, each using a variety of different materials and processes. By current standards, processing composite components to a tolerance required for a shimless assembly does not occur because of the lack of dimensional control. To compensate, design engineers leave gaps to allow for variations in part dimensions, thereby eliminating part-to-part interference. In doing so, however, the designers also generated a requirement for shimming - a long complicated manufacturing process which can add several days to factory flow time, and requires skilled mechanics to match parts and shim the gaps to ensure accurate fit and minimal pre-load. Eliminating the need for some shimming can improve the total quality of the aircraft structures, lower assembly costs, and save manpower. Directorate research engineers and other 400ER team members, under the Process for Dimensional Control program, successfully generated a set of tooling compensations for use with production 767-400ER spar tooling. This tooling eliminates the requirement for shimming at the eight joints in the wing tip assembly. The 400ER team incorporated these changes and fabricated at least four sets of raked wing tips. Projected savings, based on the initial wing tip production, include: a savings for shim procurement of approximately $65,000 over 300 ship-sets; an assembly labor savings of about $50,000; a total recurring savings of $115,000 for the winglet alone; and a potential cost avoidance of $410,000, assuming 100% of joints incorporated shimless assembly. This cost analysis represents the most accurate assessed value of the winglet savings to date.

Casting Supplier Initiative Reduces Cost of Aircraft Gas Turbine Engines



Payoff

The steady flow of product and process improvements and cycle-time reductions demonstrates the success of the Engine Supplier Base Initiative (ESBI) program. The core savings on Air Force parts alone is greater than the total sum of ESBI dollars invested at the Morristown Casting Support Facility. The benefits from the ESBI are significantly greater when looking at the full spectrum of projects at the 12 Howmet and Precision Castparts Corporation sites actively involved in the casting operations portion of this program.

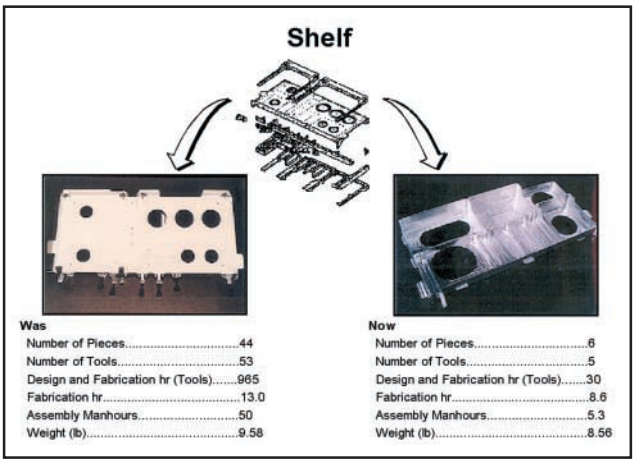
Accomplishment

Under a cooperative agreement with the Materials and Manufacturing Directorate, Howmet Corporation and Precision Castparts Corporation significantly lowered the cost of manufacturing aircraft gas turbine engines. Four projects improved processes, improved quality, reduced scrap, and reduced cycle-time in the manufacture of these engines. The directorate anticipates even greater improvements as these projects continue.

Background

The use of gas turbine engines on many Air Force and commercial aircraft contributes to a significant part of the total cost of these aircraft. The directorate established ESBI, also known as the casting supplier initiative, to identify and implement manufacturing improvements in a key portion of the gas turbine engine industry. Sponsored by the directorate's Manufacturing Technology Division, the ESBI targets cost and cycle-time reductions in the manufacture of cast airfoil and large structural components for these engines. Implementing technical advances in the engine-making foundries achieves these reductions. As part of the casting supplier initiative, Howmet's Morristown Casting Support Facility conducted a set of projects that dramatically impacted the cost and quality of ceramic cores used to create engine castings. Four projects show significant benefits and improvements in core manufacturing operations, resulting in casting product improvements. Better core dimensional control leads to improved casting dimensional control, reduced scrap, reduced core breakage during wax injection, and the ability to tighten casting tolerances. The goal of the Core Dimensional Improvement project is to reduce the standard deviation of the fired core contour by 50%. Reducing this characteristic will lead to less dimensional scrap and lower prices. The Reduction in Broken, Cracked, and Chipped Cores project is trying to reduce core breakage by 50% over the life of the program. The Reduction in Compound Thermal Variation project's goal is to reduce dimensional and visual variation in raw materials, batched materials, and thermal treatments by a minimum of 25% per year. Researchers achieved a 48% improvement by installing new preheating units, modifying transfer molding compounds, and working with key raw material suppliers on delivery, quality, service, and price. A new roll mill, better tailoring of material properties, and other processing enhancements will result in continued improvements. The Cycle Time Reduction project has achieved an impressive 39% reduction in shop-wide cycle time as a result of cell balancing, scheduling and buffering refinements, and one-piece flow concepts. This project reduced inventory, and researchers also seek to reduce the number of pre-bake cycles, thus improving the scheduling system.

Precision High-Speed Machining Improves Quality of Aerospace Structures



Payoff

This precision, high-speed machining with vibration control system will benefit the machine tool industry by allowing the production of extremely flexible, lightweight, high-quality, aluminum aerospace structures at low cost. Reduction in the number of manhours, tools, and parts required to create these structures will result in a cost avoidance of $20 million. Subsequently, the system will provide an increased capability to produce lightweight aerospace structures at an affordable cost.

Accomplishment

Under a contract with the Materials and Manufacturing Directorate, the Boeing Company developed a precision, high-speed, vibration-controlled machining system that will revolutionize the machine tool industry's ability to produce aluminum aerospace structures. The system's estimated $20 million cost avoidance over five years, will reduce the weight, number of tools and parts required, and manhours necessary to create these structures.

Background

Aerospace components produced through high-speed machining have fewer parts, less weight, and better quality. In order to produce these high-quality aluminum structures, the machine tool industry requires a high-speed, high-feed-rate, multi-directional, precision milling capability. Several speed and vibration factors that prevent high-speed machines from reaching their maximum metal removal rates during machining limit the current technology. Three main obstacles limit the metal removal rates of these high-speed machines: 1) vibration, leading to damaged part surfaces, 2) low-feed rates and accelerations, leading to excessive slow down and time spent in cornering, and 3) limited path accuracy at higher feed rates, resulting in errors. Program engineers developed a very flexible and dynamically stable high-speed, high-feed-rate, multi-directional machine tool for producing high quality aluminum aerospace structures with minimum weight and fewer parts. Under a contract with the Air Force Materials and Manufacturing Directorate, the Boeing Company of St. Louis, Missouri, assembled a team for this task. Boeing's team included Ingersoll Milling Machine Company of Rockford, Illinois; Setco of Cincinnati, Ohio; General Dynamics-Advanced Technology Systems of Arlington, Virginia; Manufacturing Laboratories, Inc. of Gainesville, Florida; and the University of Florida. The team established the performance requirements of the machine tool, designed and developed the vibration control technologies used on the tool, fabricated and assembled the machine tool, and demonstrated its capabilities. In addition to the vibration control capability, the machine tool uses innovative design approaches and an "open architecture" controller, which provides user flexibility and the capability to add other technologies. Boeing engineers installed and demonstrated the machine tool in their St. Louis Advanced Manufacturing Technology facility. The project has improved state-of-the-art high-speed machining, machine design, open architecture controls, and linear motor technologies.

Low-Cost, Composite-Bonded Wing Achieves Significant Part and Cost Reduction

22

Payoff

A joint project with the Materials and Manufacturing Directorate and Air Vehicles Directorate reduced the cost and number of parts used in a V-22 composite wing box. The effort used novel, innovative composite design technologies, as well as materials and manufacturing processes, to reduce cost by 50% and eliminate 75% of the required fasteners.

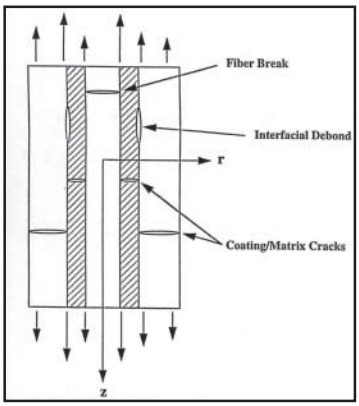
Accomplishment

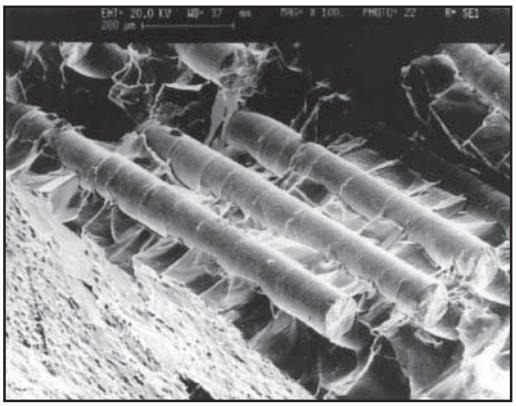
This program, one of the Design and Manufacture of Low-Cost Composite programs, developed the technology essential to reduce the cost of wing, fuselage, and engine structures for future aircraft. The program also significantly reduced assembly costs and exceeded the overall cost reduction goals. Engineers transitioned the bonded rib-to-skin interface methodology to the Bell 609 commercial tilt-rotor. Development of this technology is continuing for possible use in future aircraft.

Background

Future weapons systems will require greater use of composite structures to meet performance and survivability requirements. Acquisition and ownership costs of these structures must be reduced, yet existing technologies provide little opportunity. Innovative new concepts are therefore necessary to enhance current composite manufacturing processes. Under contract with the laboratory, Textron Corporation (Bell Helicopter Division of Fort Worth, Texas) engineers demonstrated the feasibility of novel materials and manufacturing processes key to achieving a 50% reduction in the cost of a V-22 composite wing. The implementation of novel, innovative, composite-design technologies, materials, and manufacturing processes achieved cost and part reduction. The resulting simplified structural assembly eliminated cost drivers and reduced cost by 50%; eliminated 75% of the fasteners in the baseline article, thereby reducing associated material, installation, and inspection costs; and introduced no weight or performance penalties. Engineers designed a new V-22 wing to increase unity and reduce the number of parts fabricated and assembled. Through the use of a concurrent engineering/integrated product development concept, the program successfully demonstrated the implementation of nascent designs, analysis, and manufacturing technologies. The Bell concept implemented extensive use of adhesive bonding of pre-cured components in a primary structure. Bell engineers bonded resin transfer molded rib webs to the hat-stiffened skin and increased bond line thickness to simplify assembly. This tolerance change had no significant impact on strength or durability. Another notable change included use of a $\pm$ 45 plies wing-skin laminate designed to increase the automatic tape-laying machine efficiency. The engineers also implemented a new material form called pultruded rods. These high-stiffness, carbon- graphite fiber rods served to recover the bending stiffness characteristics in the wing. Engineers at the Air Force Structural Test Laboratory tested the V-22 demonstration article for sufficient strength, stiffness, durability, and damage tolerance.

Axisymmetric Damage Model Can Lower Design Cost of Structural Composites





Payoff

The extremely reliable Axisymmetric Damage Model (ADM) provides clearer understanding of crack growth in composite structures. Using this model, engineers can create design concepts and options more efficiently and at lower cost. The model helps designers understand reasons for composite material failure and allows development of new lamination theories for aircraft and spacecraft structures, while saving time and testing costs.

Accomplishment

New modeling software developed at the Materials and Manufacturing Directorate may help the Air Force, Department of Defense, and the commercial aviation industry realize extensive design cost savings. The ADM can reduce actual testing requirements through the use of highly accurate calculations and simulations, resulting in reduced design time and faster product delivery.

Background

Empirical research methodology verified only through extensive qualification testing typically provides the basis for composite structural designs for aircraft and space vehicle systems. Despite the testing, too many variables that are inherent in the composites exist to permit adequate characterization. Structures that are not optimized, are overweight, or unsafe result. One of the most critical challenges facing design engineers is understanding the transverse cracking phenomenon, especially in composite materials used to manufacture aircraft structures and space systems, such as advanced satellites, where stringent dimensional requirements must be observed. Establishing a proper mechanics foundation for understanding steady state cracking, which is common during transverse cracking; is a major component of this challenge. Specifically, design engineers examined the role of steady state cracking, identified analytical tools to characterize it, and defined its relevance in composite technology. A veteran directorate scientist, Dr. Nicholas J. Pagano of the Nonmetallic Materials Division, investigated the traverse cracking phenomenon for several years. His research led to the successful development of the ADM, now used to characterize damage incurred by various types of composite materials, many of which support Air Force systems. The ADM is also preparing the way for rigorous failure criteria and the development of new lamination theories for aircraft composites and space applications. Achieving multitudes of design and material concepts and options through calculation and computer simulation is a result of this safe, highly efficient, cost-effective process. Steady state cracking, introduced about 20 years ago, was not calculated accurately prior to Dr. Pagano's research. His involvement successfully derived and implemented a rigorous three-dimensional, path-independent contour integral. The modeling of ply-level damage, such as transverse cracks in off-axis layers and delamination between adjacent layers of different fiber orientation, is of primary importance in predicting the failure of composite laminated structures. Transverse cracks often result in loss of strength and stiffness, and changes in the coefficient of thermal expansion, any of which can have a detrimental impact on active systems. The cracks also provide pathways for moisture and other corrosive agents, and are precursors of the fatigue process.

Biologically-Inspired Camera System

24

Payoff

Comptek Amherst Systems, Inc. recently delivered a novel vision system to the Munitions Directorate under an ongoing Phase II Small Business Innovation Research effort. This real-time, non-mechanical, reconfigurable vision system acquires and tracks objects based on the biological concept of foveal vision. This closed-loop targeting system is beneficial to any bandwidth-constrained application that requires simultaneous wide field of view surveillance, localized high resolution, and fast frame rates. The ability to switch modes of operation on a frame-by-frame basis gives this system robustness and an error recovery capability that has not been achieved by traditional mechanically-based vision systems.

Accomplishment

The camera allows wide field of view surveillance with localized high resolution in an area of interest. This new electronically reconfigurable system reduces the typical image-processing data throughput bottleneck to allow real-time target acquisition and tracking in one compact system. The unique design is small, inexpensive and eliminates the need for large power supplies and mechanical gazing mechanisms. Several applications that benefit both the military and commercial sectors include search and rescue capabilities, intruder security and surveillance, and autonomous robots for security applications. The system could also be used for wireless networked cameras, particularly for military applications such as network-centric warfare and remote surveillance. State-of-the-art seekers for precision munitions and unmanned aerial vehicles are also military specific applications, while assembly line part inspections and quality control uses are of benefit to the commercial sector.

Background

Electro-optic sensors are evolving from single color 128x128 arrays to multicolor 1000x1000 arrays. Biological vision systems incorporate a small area of high resolution (fovea) within a wide field of view having a lower resolution. This biologically-inspired vision system is able to track targets over a wide field of view at a video rate using a personal computer (PC) with no special digital signal processing equipment. The hybrid tracker can locate and track even partially occluded targets. The vision system was successfully used to detect and track human faces and a model train on a simple circular track. The prototype reconfigurable vision system consists of three main hardware components: a foveal camera, power supply, and host PC. The camera contains a visible imager and lens along with support electronics and interface connectors. The foveal camera consumes very little power. The 60-mW camera can be powered for several hours by a single 9-volt battery or indefinitely by a standard AC power adapter. The third component of the prototype foveal vision system is a Windows NT® host PC. Targeting algorithms, video processing, and configuration control all execute on the Pentium® with no additional processors. The prototype foveal vision system incorporates three software modules implemented as real-time priority programs in Windows NT®: a Detection and Tracking Algorithm module, a Control module, and a Data Acquisition module. Today, a pilot must monitor several distributed sensors to identify incoming missile threats. With a biologically-inspired vision system, the pilot can respond more quickly to an incoming missile threat when a single sensor autonomously identifies the threat and warns the pilot. Biologically-inspired vision systems can conceptually aid all types of fire-and-forget munitions in much the same way.

Shifting the Paradigms of Revolutionary Ordnance and Guidance Technologies

Payoff

The Munitions Directorate committed a significant portion of its applied research budget to the pursuit of "revolutionary" technologies. The goal of this high-risk, high-payoff, research effort is to discover munitions-related technologies that dramatically change the way the Air Force fights future conflicts. The military payoff will be in terms of significant weight and size reduction of munitions, reduced weapon cost, and improved effectiveness.

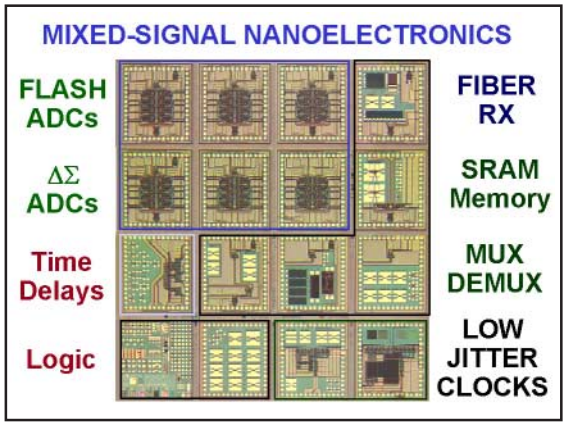
Accomplishment

The directorate initiated a Revolutionary Technology (Rev Tech) program to create new airframe/ordnance and guidance/control paradigm shifts in technology. The principal goal of the program is to discover and foster technologies that may be the springboard to the development of highly innovative solutions to defeat a variety of targets. This includes fixed and moving targets, hard and soft targets, and above ground and deeply buried targets. Another purpose of this program is to develop highly innovative concepts and approaches in guidance and control technologies for air-deliverable autonomous munitions. The Rev Tech program may develop advanced concepts in such areas as electro-optical, infrared, millimeter wave, and radio frequency seeker technology with the components and signal/image processing systems used in munition seekers. The program also seeks advanced concepts in the guidance, navigation, and control (GN&C) of munition airframes with particular emphasis on the GN&C of miniaturized vehicles, both airborne and ground mobile.

Background

Both large and small companies, as well as academia, solicit research ideas through the issuance of an updated Broad Agency Announcement (BAA) published each March. The BAA, accessible via the Internet at www.eps.gov, invites interested parties to submit white papers to the directorate. These white papers briefly describe the proposed research and potential pay-off to the Air Force. Due to funding constraints, only about one out of five papers emerges from this process. Since these research efforts are "proof of principal" only, the awarded proposals are less than $300,000 and typically run for one to two years. Specific research areas of interest include, but are not limited to, target location methods, multi-mode explosives, cooperative weapon technology, integrated guidance, munitions speed and maneuverability, standoff distance enhancement, munitions component parts reduction, networked communication and intelligence, munitions knowledge (artificial intelligence), multifunctional damage mechanisms, non-lethal technologies, and munition environmental pollution prevention. The technologies developed under this program will support the far-term goals of the directorate's Anti-Materiel Munitions, Small Smart Bomb, Hard Target Smart Munitions Hard Target Functional Defeat, Close-Air-Support, Air Expeditionary Force, Counter-Proliferation, and Air Superiority Missile Technology Integrating Concepts. Currently, eight individual efforts are under contract, with another two earmarked for early fiscal year 2001 award. Starting in fiscal year 2001, the directorate will also issue its first Campus Challenge, a competition held among a set number of the country's recognized engineering universities. Air Force Office of Scientific Research selection criteria serves as the basis to select the universities..

Resonant Tunneling Diode Research May Benefit Integrated Circuits



Payoff

Projected resonant tunneling diode (RTD) benefits include improved battlespace awareness and battlespace management, more effective radar receivers and missile seekers, and reduced logistical support. Products incorporating RTD technology can double the current data transfer rates, while reducing the number of components ten-fold. Additionally, power consumption could drop anywhere from 10-2,000 times.

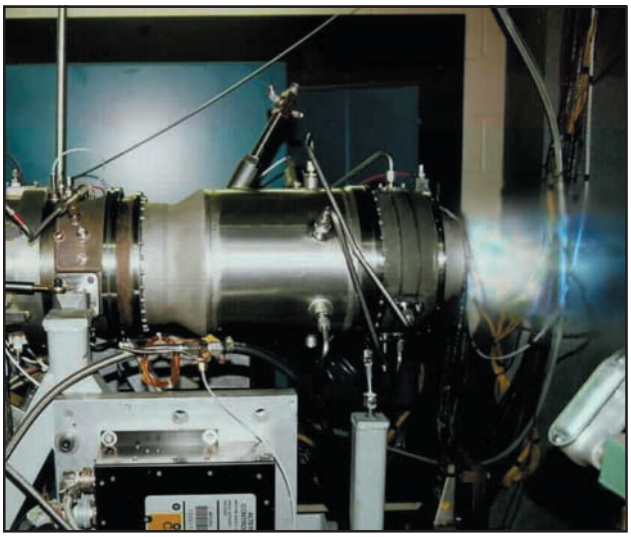
Accomplishment

The Air Force Office of Scientific Research (AFOSR) initially funded a research grant to Texas Instruments (TI) Central Research Laboratory (now part of Raytheon) to conduct RTD research. AFOSR then served as technical agent for a scaled-up research program funded by the Defense Advanced Research Projects Agency and performed by TI/Ratheon, teamed with five universities. The RTD, as developed by the TI/Ratheon team, consists of a set of three ultra-thin layers. Those layers, a "well" of silicon sandwiched between two barrier layers of silicon dioxide with electrical contacts on the top and bottom, permit operation in several electrical states with as many as 19 different current steps. By contrast, the ordinary transistor has one operating step – from on to off or vice versa. The greater electrical flexibility of an RTD enables it to represent several logic states, thereby doing the work of several conventional transistors. This leads to more complex logic units with fewer electronic parts. Such electronic systems also are smaller, need less power, and are easier to harden to the harsh environments of space and modern warfare. Equally important, the fabrication of this new hybrid electronic technology is compatible with the traditional silicon circuitry.

Background

In today's logic circuits, the smallest features of transistors and connecting wires are about 50 times narrower than a human hair, or about 0.35 microns (a micron is a millionth of a meter). A state-of-the-art logic chip contains about four million transistors per square centimeter, an area about the size of a small fingernail. The semiconductor industry plans to continue doubling the number of transistors on a chip every three years. According to that plan, state-of the-art transistors will be almost 10 times smaller in 15 years while containing nearly 10 times the transistor count. Transistors work much like a light switch in that they permit electrical current to be turned on and off. When they are turned on, electrons flow to other parts of the circuit. Likewise, when turned off, they block electron flow. Problems, as well as opportunities, arise in turning the transistor on and off when the barrier is as small as the wavelength of an electron. Even when the switch is turned "off," some electrons can actually disappear on one side of the barrier and reappear on the other side. The phenomenon, known as tunneling, makes the transistor act like a leaky faucet. However, when properly constructed and operated, the leaking, or tunneling, can be made to occur in one or more discrete steps of electrical current. The new device is called an RTD. While potentially useful as discrete devices, RTDs show great promise when used in conjunction with ordinary transistors.

Successful Test Brings AFRL Closer to Expendable Turbine Engine Goals



Payoff

The Phase II first build of Williams International's Joint Expendable Turbine Engine Concept (JETEC) engine, the XTL-86/1, successfully completed testing in 1999 at Williams International facilities in Walled Lake, Michigan. The JETEC demonstrator is pursuing the Propulsion Directorate's Integrated High Performance Turbine Engine Technology Phase II supersonic expendable engine goals, which are a 45% reduction in cost and a 70% increase in specific thrust.

Accomplishment

The XTL-86/1, which ran from idle to 100% mechanical speed, established an engine control schedule for future demonstrations. The sea-level static results equate to a 40% increase in specific thrust compared with the baseline J402. The XTL-86/1 test results allowed testing to begin on the XTL-86/2, which replaces the metallic hot section with ceramic composite and carbon-carbon parts. This new technology enables a 75% increase in cruise speed and approximately a 40% decrease in reaction time relative to the baseline J402 engine that powers the Harpoon missile.

Background

The XTL-86 has two configurations: one with an all-metal hot section and one that utilizes ceramic components. The ceramic turbine will allow engines to exceed metallic engine capabilities. The ceramic hot section is less expensive and critical to meet the JETEC cost goals. The XTL-86/1 is an all-metallic configuration that demonstrated a forward-swept shrouded compressor, a high-heat release combustor, and hybrid ceramic fuel-lubed bearings. The success of the XTL-86/1 paved the way for the second build, the XTL-86/2, which will be tested at Arnold Engineering Development Center in Tennessee. The XTL-86/2 has an uncooled, high-temperature section with a carbon silicon-carbide (C/SiC) turbine rotor, C/SiC turbine nozzle, and a carbon-carbon exhaust nozzle. It will be tested at the Phase II goal demonstration point for approximately 10 hours at operation equivalent to Mach 1.0+.

Innovative Engine Technology Demonstrates Potential to Revolutionize Turbine Engine Performance

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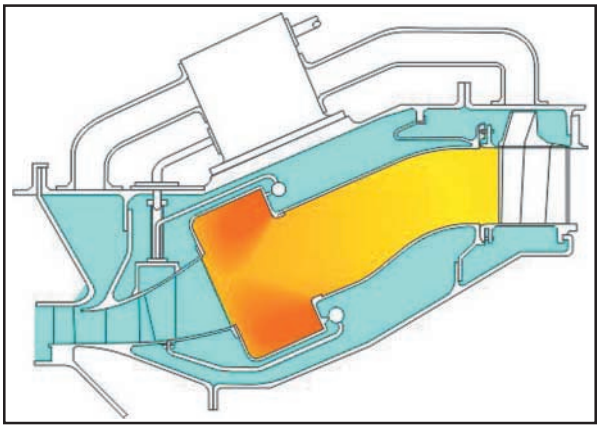


Payoff

The Propulsion Directorate, in partnership with General Electric Aircraft Engines (GEAE), developed the trapped vortex combustion (TVC) technology, which demonstrated significant improvements in performance and drastically reduced emissions. The TVC, a revolutionary approach to aircraft combustor design, has the potential to reduce lean blow-out, while significantly reducing oxides of nitrogen (NO_x) and volatile organic compound (VOC) emissions. Turbine-powered Navy ships using TVC could also benefit from the improved overall performance provided by trapped vortex combustors. GEAE's integrated high performance turbine engine technology Phase III engine will use a TVC designed for ultra-high performance

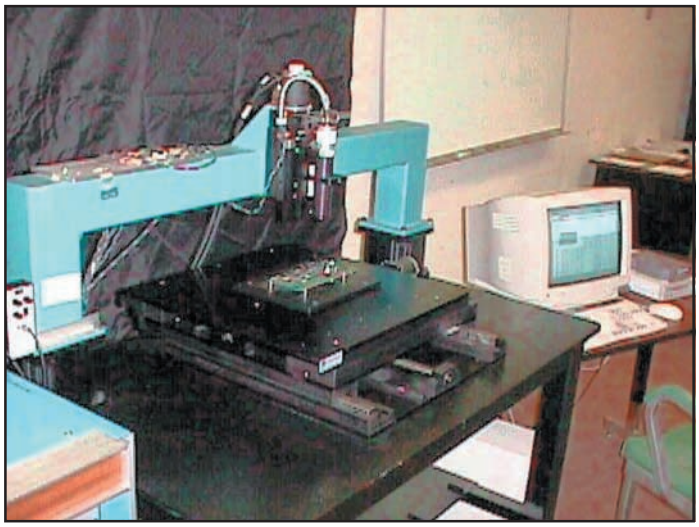
Accomplishment

The Propulsion Directorate's Combustion and High Speed Systems Branch is working with General Electric on a radically new combustor design based on the trapped vortex principle. The 12-inch trapped vortex combustor sector prototype, tested at the directorate's Wright-Patterson Air Force Base facility, demonstrated a 55% reduction in aircraft NO_x emissions and a 50% reduction in VOCs based on typical in-service engine experience. Performance, of the TVC test article demonstrated a 58% reduction in the lean blow-out limit and a 42% increase in altitude re-light capability. In addition, data from these tests indicate that Navy turbine-powered ships could reduce yearly NO_x emissions by 55% and VOCs by 50% compared to the LM2500 turbine engine commonly used.

Background

The Air Force Office of Scientific Research sponsored the TVC concept, which grew out of fundamental studies of flame stabilization conducted by the directorate. The TVC is a radical departure in combustor design from the 40-year tradition of using swirl cups to stabilize the flame inside the gas turbine engine combustors. While swirl-stabilized combustors perform well, combustion stability is somewhat limited and, therefore, can blow out in certain parts of the engine's operating envelope. The trapped vortex combustor maintains a high degree of flame stability. Since the vortex trapped in a cavity provides a stable recirculation zone that is protected from the main flow of the combustor, the cavity serves as a pilot flame and provides a continuous ignition source for the main combustor, helping to keep the flame lit throughout the operating envelope. This interaction between the cavities and main combustor significantly enhances mixing, allowing for a short length, compact combustor. The low NO_x emissions are primarily the result of improved fuel and air mixing in the cavity and the front end of the main combustion zone. The current program is a partnership between the Air Force, Navy, Department of Energy, Strategic Environmental Research and Development program, and GEAE.

Software Increases Fidelity of Simulation Testing Environments



Payoff

The non-intrusive test and evaluation system (NITES) software increases the fidelity of the simulation laboratory through a more realistic testing environment. The software demonstrates new sensor technologies in the laboratory that are more controllable and less expensive than flight-testing, thus, saving time and money. It also decreases the number of flight test hours needed to transition sensor technology to military aircraft.

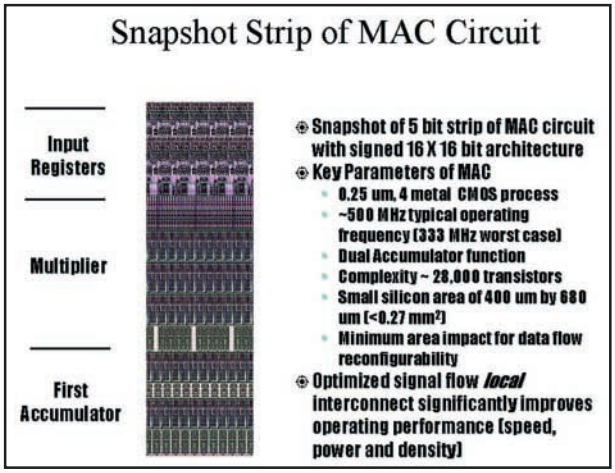
Accomplishment

The Sensors Directorate, working with Defense Research Associates under a Small Business Innovation Research program, developed an innovative software solution to improve the fidelity of "system of systems" simulation environments, making sensor testing more accurate and cost effective. The NITES software monitors sensor hardware components and provides outputs which, when fed back into the simulation, create a more realistic testing scenario, saving time and money.

Background

As sensor technology becomes more sophisticated, testing becomes increasingly complex and expensive due to the requirement for electronic countermeasure (ECM) systems to meet stringent evaluation criteria prior to transition to an aircraft. One approach used to reduce the cost of testing was the creation of a simulation test environment. In the past, a laboratory, where possible threats were fed into the test simulation, monitored the ECM system's response to individual stimulations. However, this limited cause-and-effect method of testing could not take into account every possibility an ECM system encounters in a real-world combat situation. Predicting the reaction of an ECM system, installed on an aircraft, to all combinations of stimuli or the effects of those stimuli was impossible. NITES software uses three main components that provide higher quality information regarding an aircraft system's response to threat situations to increase the fidelity of simulation environments. The three components are an ECM system interface module, a jammer simulation module, and a local object broker interface module. Rather than using a cause-and-effect testing environment, NITES provides the ability to feed hardware responses into the simulation. NITES' main objective is to improve the environment fidelity, which will complement the "system of systems" virtual synthetic battlespace hardware/pilot-in-the-loop capability. Environment fidelity gauges the response of aircraft sensors to multiple threat environments before transitioning those sensors to aircraft/space vehicles.

COARSE GRAINED RECONFIGURABLE COMPUTER



PAYOFF

Researchers from the Sensors Directorate, in conjunction with Infinite Technology Corporation (ITC), demonstrated a technology that enables a new custom configurable parallel processing system on a single computer chip. This new technology is over 10 times faster than technology available in industry today and will provide both military and commercial platforms with faster and more flexible processing and communication capabilities.

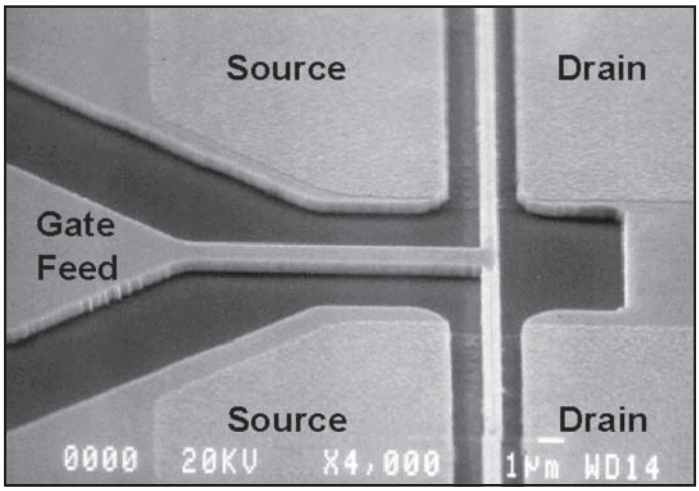
ACCOMPLISHMENT

Directorate personnel working with ITC, an intellectual property company that licenses digital signal processing (DSP) coprocessor cores, successfully completed the technical feasibility demonstration of a single-chip coarse grained reconfigurable computer (CGRC) that includes multiple (222 MHz) multiplier-accumulators (MACs) and patented reconfigurable interconnect fabric using a 0.25 micron complementary metal oxide semiconductor fabrication process. For the first time, a system-on-a-chip designer can quickly configure application specific instruction coprocessors to accelerate a set of data stream algorithms from a library of components pre-designed for high-performance and low-power dissipation.

BACKGROUND

Manufacturers have used programmable signal processing chips on current Air Force aircraft systems for many years. These older programmable devices connect to memories and other devices by bus architectures that create bottlenecks in processing and operate at very low speeds. Fine grain reconfigurability where field programmable gate arrays support dynamic circuit modification, but typically have long reconfiguration times that prevent real-time processing adaptability, generally characterizes current adaptive computing. The new CGRC architecture integrates high-performance DSP functional units (like the MAC), reduced instruction set computer (RISC) microprocessors, and memory architectures all on the same piece of silicon. RADcore™ technology enables the chip to provide two levels of reconfiguration–custom configuration of functional units during silicon-integrated circuit design and run-time reconfiguration by very long instruction word for efficient, adaptable, algorithmic processing performance. For example, imagine that engineers load several radar-processing algorithms on an aircraft. As the target comes in range, the radar locks on and switches to a higher-resolution algorithm to zoom in on the object. Using CGRC technology, the controller reconfigures the programming and connectivity of the hardware used, and the RADcore-based CGRC accommodates the new algorithm processing in a real time, efficient manner. Since a single silicon device contains both the DSP functional units and RISC processor, on-chip communication and shared memory eliminate off-chip communication bottlenecks and greatly improve performance. Engineers can program up to 15 functional units with 250 million DSP operations-per-second per-functional-unit to achieve high performance and flexibility previously only dreamed about. CGRCs have many military applications, such as aircraft sensor, control, and communications, as well as commercial applications found in automotive/industrial sensor and control, cellular telephones, high-definition TV, and multi-media.

Single Layer Integrated Metal Process Simplifies Method for Fabricating Field Effect Transistors



Payoff

The simplified single layer integrated metal (SLIM) process is less expensive and more accurate than the conventional field effect transistor (FET) fabrication process. The resulting device is a single layer integrated metal field-effect transistor (SLIMFET) that is suited for use in analog transistor applications.

Accomplishment

Scientists at the Sensors Directorate developed a new, less expensive, and more precise process for fabricating FET that simplifies the forming of metal contacts. The resulting SLIMFET 59 gigahertz cut-off frequency is electronically comparable to conventional devices.

Background

Fabricating FET is a complex process requiring precise manufacturing tolerances. Metals or composites alternately mask, etch, and deposit on a piece of substrate material. Executing these operations properly will result in a FET with highly predictable electrical and physical properties. Although the process varies depending on the type of transistor fabricated, it always requires the application of metal or composite onto the Schottky gate contact and the drain/source contacts to provide a path for electron flow. The conventional method for filling these contacts involves two complete series of masks, etches, and deposits for each type of contact. Perfect alignment of the masks and etches requires high precision. The SLIM process uses a single series of steps to apply metal to the Schottky and drain/source contacts simultaneously. Before this application, a secondary masking layer of silicon nitride is applied and a primary mask is added. The surface is then etched to create the holes in the mask at the desired location for the contacts and chemical deposition allows the metal to cover the entire surface of the FET. Removal of the primary mask's unwanted metal leaves the contacts covered with the conducting metal. After the FET process is complete, the addition of a secondary silicon nitride mask provides an additional outer protective shell for the FET. The resulting device is a SLIMFET. Since this process affects only the uppermost layers of a FET substrate, it can be used on a variety of transistors including the metal semiconductor FET, the high electron mobility transistor (HEMT), and the pseudomorphic HEMT.

The Impact of Scintillation on GPS Effectiveness

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Payoff

The National Security Space Architect (NSSA) requested a study to determine the impact of scintillation on global positioning system (GPS) military weapon system effectiveness. This study provided insight on scintillation and its impact on GPS systems in the future. The efforts of the Advanced Concepts Exploration (ACE) team have directly impacted the NSSA space weather architecture, paving the way for follow-on space weather research.

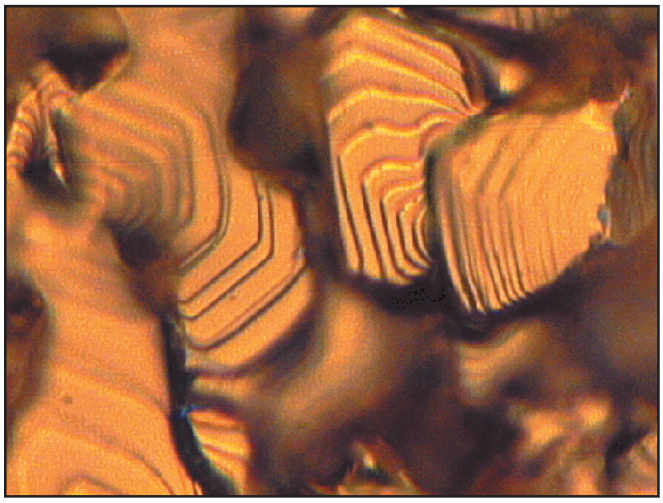
Accomplishment

Scientists in the Sensors Directorate successfully modeled the effects of ionospheric scintillation on the GPS radio frequency (RF) signal. This space weather phenomenon is of growing concern due to increased reliance on GPS for various military weapon systems and civilian infrastructure. Findings will better prepare civilian and military authorities to meet future challenges associated with ionospheric scintillation and other space weather phenomenon. The Department of Defense is also issuing a new policy on future space weather architecture.

Background

The 11-year solar cycle, commonly referred to as Solar Maximum, predicts solar activity to peak during the year 2000. This increase in solar activity will generate substantial electromagnetic atmospheric effects on RF signals passing through the earth's ionosphere. One such effect, known as ionospheric scintillation, is characterized by rapid changes in signal phase and amplitude. Although this effect is expected to have a greater impact around the magnetic equator and polar cap regions, the total impact on the GPS system is unknown. In collaboration with the Space Physics Model Branch and partially funded by the Air Force Office of Scientific Research, the directorate began to model this phenomenon in the ACE laboratory. Scientists integrated simulated mild, moderate and severe ionospheric weather conditions into the directorate's antenna wavefront simulator (AWFS), collecting more than one gigabyte of test data on a representative set of military and civilian GPS receivers in order to demonstrate the effects of ionospheric scintillation on receiver performance. For this innovative experiment, directorate scientists reconfigured the AWFS to generate RF phase and gain under simulated ionospheric conditions, and captured actual GPS hardware performance. The NSSA received briefings on this experiment and requested a study, completed in less than two months, to determine the impact of scintillation on GPS military weapon system effectiveness. Mission modeling based upon the GPS Joint Program Office's navigation warfare effort, showed significant impact on GPS performance during a simulated military conflict. As a result of this Phase I study effort, NSSA recommended implementation of a space weather architecture and initiation of a Phase II study effort.

LaS-Based Emitters Could Benefit Electronic Warfare Community



Payoff

By using lanthanum monosulfide (LaS) as a basic material to build emitters, researchers can produce higher power capacity microwave power tubes, which are lighter and smaller than tubes currently in use. Initially, missile seeker and standoff jammer applications would significantly benefit from this development. Eventually, a class of microwave tubes could be produced that is more powerful and reliable, yet lighter and smaller.

Accomplishment

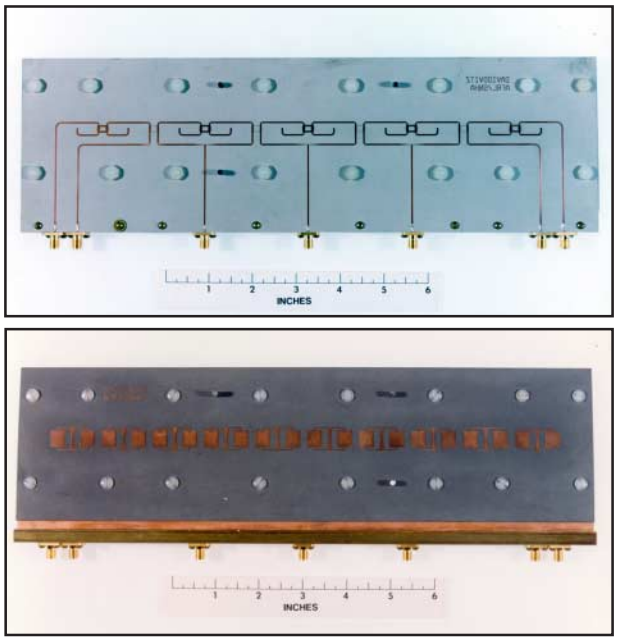
Scientists from the Sensors Directorate, in conjunction with the University of Cincinnati, developed a method to synthesize bulk quantities of LaS for use in solid-state emitters, which could provide high power, more efficient microwave power sources. Since LaS is not commonly available, production of LaS crystallites in sufficient quantity to fabricate a sputtering target required a practical method of synthesizing. With the synthesized target researchers can now explore LaS as a deposited material for cold cathode structures, which are specifically useful for the electronic warfare community requiring high power, highly efficient microwave power sources.

Background

Historically, manufacturers used thermionic cathodes in tubes to produce microwave power. However, thermionic cathodes typically produce 1-2 A/cm^2 current density, require a heater element, exhibit problems with reliability, and require velocity modulation of the resulting electron beam to amplify microwave signals. Researchers realized the need for a more efficient electron emitter and designed a cathode which could produce high current density (greater than 10 A/cm^2) without heating, and have the capability of direct modulation of the emitted electron beam. Directorate researchers conducted theoretical investigations which indicated LaS-based cathode structures could satisfy these goals. LaS should provide a low work function surface critical to operation of solid state electron emitter devices. Achievement of a successful process to synthesize bulk crystallites of LaS produced a target suitable for use in thin film sputtering equipment, thus allowing experimentation with various cathode structures containing a deposited film of LaS at their surface.

Major Breakthrough in Low-Cost, Lightweight, Limited-Scan Arrays

34



Payoff

By using a unique feed design, manufacturers can make limited scan antenna array assemblies lighter, cheaper, and more efficient. Use of the overlapped feed affords a reduction of up to three times the number of active components, with a comparable decrease in the cost of the phased array.

Accomplishment

A Sensors Directorate in-house project demonstrated the implementation of an integrated overlapped array design in planar circuit form for air and space-based radar systems. This innovative feed network greatly reduces the number of active radar components needed to scan over a limited field-of-view, with a comparable decrease in cost and weight and the benefit of increased performance.

Background

Most space-based radar systems, as well as a number of airborne communication and surveillance platforms, include phased array radar systems with limited scan requirements. Manufacturers can significantly reduce the number of active transmit and receive modules needed to scan a phased array beam over limited field of view from the conventional one module per element system by employing overlapped feed structure. This is a well-established concept, with many feed designs already known. However, in the past, the practical implementations were bulky. By employing multi-layer microstrip technology, directorate scientists "folded" the feed networks into a compact, modular bonded layer structure. To meet the scan requirements of many proposed radar systems, the demonstrated linear overlapped array can be replicated to assemble large, thin flat-panel arrays. Use of this innovative feed design allows the antenna structure to meet stringent low weight and small stowable volume requirements of critical space radar systems.

Aeroelastic Wing Technology Enhances Maneuverability at High Speeds

Payoff

The Active Aeroelastic Wing (AAW) Flight Research program focuses on developing and transitioning the application of aeroelastic-based wing concepts to control aeroelastic twist at high speeds, resulting in improved roll maneuverability and the potential of eliminating horizontal tail surfaces.

Accomplishment

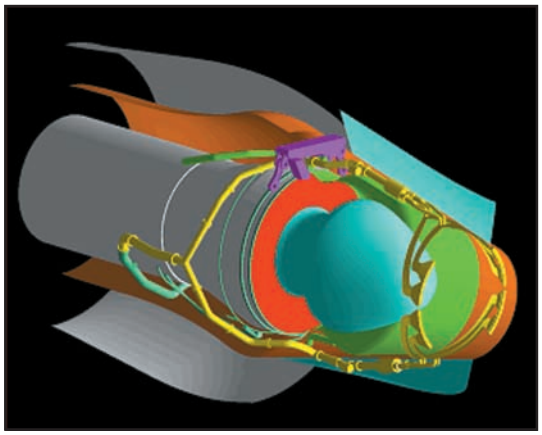
Under the AAW Flight Research program, the Air Vehicles Directorate, in cooperation with the National Aeronautics and Space Administration's Dryden Flight Research Center and Boeing Phantom Works, is researching a "wing warping" approach to control aeroelastic warp or twist for a net benefit. AAW technology application advantages include substantially increased control power from conventional control surfaces, such as ailerons and leading edge flaps, through reductions in aerodynamic drag and structural weight. Specific application of AAW in recent studies demonstrated that AAW technology reduces aircraft takeoff weight by 7-10% for subsonic cruise configurations and 20% for supersonic cruise configurations. Additionally, since use of AAW technology can generate total aircraft roll authority entirely with the wing, the use of differential tail deflections for roll control, such as those found in the F-14, F-15, F-16, and F/A-18, is no longer necessary. This allows reduction and the potential for total elimination of horizontal tail surfaces.

Background

The Wright brothers designed their first aircraft without the use of ailerons or flaps to control the airplane; instead the pilot controlled aircraft rolling by moving his hips from side to side and "warping" the wingtips. Today's high-speed aircraft wingtips aeroelastically warp or twist at very high speeds, which often has negative effects. AAW technology is a novel approach providing powerful rolling control forces for high-performance aircraft. This technology is especially synergistic with thin, flexible wings and allows more freedom to exploit highly-efficient, thin, higher-aspect ratio aerodynamic wing platforms. A lightweight flexible wing will now have a positive control benefit rather than a negative one. The research program is evaluating the AAW concept with the goal of developing flight data for transonic and supersonic flight.

New Pulsed Air Injection System Enhances Survivability and Saves Money

36



Payoff

In the mid-90s, the Air Force recognized a need to eliminate the core thrust reverser (CTR) on C-17 aircraft. The CTRs were originally designed to meet the Air Force requirement for backing the aircraft and to maintain tolerable temperature levels for personnel at the rear of the aircraft during engine-running off-load operations. The Air Vehicles Directorate, in partnership with the Defense Advanced Research Projects Agency, the Joint Technical Coordinating Group for Aircraft Survivability, and Boeing, actively sought alternatives to CTR technology. Active core exhaust (ACE), the most promising alternative to the CTR, is a fully integrated, non-intrusive pulsed injection system, which creates a rapid decrease in plume core temperature.

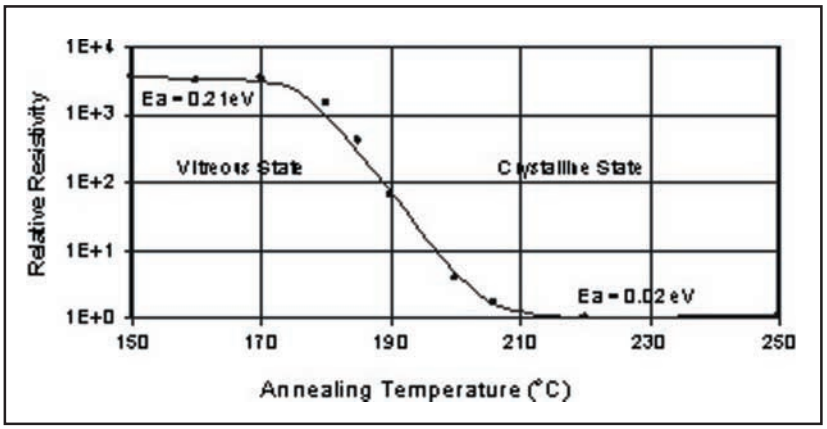
Accomplishment

After a successful demonstration on a sub-scale missile engine in 1996, the low-bypass ratio JT8D engine performed a proof-of-concept ground test in 1997. The test successfully demonstrated that when ACE is turned on, normal engine operation continues and a 50% reduction in exhaust plume temperature is a realistic expectation. Furthermore, this ground test provided experimental data to develop and validate a computational fluid dynamics model for use in trade studies of the high-bypass ratio design, eventually leading to a fully integrated full-scale ground-test demonstration. Proof-of-concept testing of the full-scale ACE system installed on an operational C-17 nacelle and instrumented F117-PW-100 engine was successful. ACE significantly reduces the exhaust plume temperature behind the engine and offers three readily achievable benefits for large transport aircraft: the elimination of the core reverser for engine running off-load and backing operations, the reduction of flap temperatures while operating in the powered lift portion of the lift envelope, and improved powered lift performance. Additionally, ACE will reduce the cost of each aircraft by approximately $1.2M and the weight of each aircraft by approximately 1,200 lbs. Most important, ACE enhances aircraft survivability through integration of a plug nozzle. This new nozzle center-body will provide 90-95% line-of-sight blockage to the hot engine components.

Background

In 1994, heavy-load transport aircraft identified the need for an advanced exhaust temperature reduction system, which ACE technology addresses. The McDonnell Douglas Corporation (now Boeing) Phantom Works pursued research into active flow control (AFC) technology for jet exhaust plumes. Simulations show pulsed jet exhaust blowing can significantly accelerate the engine plume rate that is mixed with the surrounding air at static and forward flight conditions. In 1996, the directorate conducted a successful demonstration of AFC-enhanced mixing and initiated a comprehensive, rapid, and low-budget experiment to verify and quantify the feasibility of the system. That testing demonstrated the viability of self-sustained AFC mixing using the ACE system. Additionally ACE addresses the Air Mobility Command's need to reduce cost and weight of the C-17 transport aircraft, while enhancing its survivability and the Air Logistic Center's desire to enhance aircraft supportability and maintainability.

Breakthrough in Computer Chip Materials Advances Security and Reliability



Payoff

Space Vehicles Directorate researchers are examining the potential of an inexpensive, non-volatile memory device for space and military applications that is virtually impervious to radiation damage or hostile electronic interrogation. It will replace current memory and storage solutions such as flash memory, electrically erasable programmable read-only memory (EEPROM) and dynamic random access memory (DRAM).

Accomplishment

Chalcogenide-based random access memory (C-RAM) promises unprecedented protection for warfighters' computer chip-based assets and may one day sufficiently pervade commercial memory products, revolutionizing the entire computing industry, from smart appliances and desktop computers to new kinds of consumer products. The current state of the art for a radiation-hardened, non-volatile memory is a 64 Kb EEPROM. Compare this to the 16 Mb C-RAM, the directorate's first, low-risk demonstration product for this technology. The capacity is 256 times greater than the best space-hardened, nonvolatile memory devices available today, and even four times the capacity of today's best space-hardened volatile static random access memory. Once perfected, C-RAM technology will enable the warfighter to process classified information on computer hardware safe from radiation damage and laser scanning.

Background

Developed more than 20 years ago, chalcogenide materials evolved to their present state and display remarkable properties. The key to these new properties is the phase change in chalcogenide materials from an amorphous state to a crystalline state by laser heating. The resulting changes in the film's reflectivity or resistivity are read with a low intensity laser for products such as digital video disk -RAM disks. Laser pulses are not the only way to store and read information in these films; pulses of electricity can also be used. Interestingly, the material has even better electrical characteristics than optical characteristics; only moderate changes (~15%) in optical reflectivity are observed while huge changes (>10,000%) in electrical resistivity are observed. In the electrically-programmable C-RAM cell, a tiny volume of the chalcogenide film is converted between the low-resistance polycrystalline and the high-resistance amorphous structural phases by resistive heating from programmed current pulses. This change in the state of crystallinity gives rise to the observed, several orders of magnitude change in resistivity. The data is then read by non-destructive detection of the cell's resistance. Electrical test measurements and computer simulations indicate programming of the cell happens in less than 50 billionths of a second at programming currents below one hundred microamps. Unlike flash memory and DRAM technologies, which work better when they are bigger, simulations indicate chalcogenide requires less energy and changes phase faster as the size of the cell decreases. In addition, early attempts at fabricating simple C-RAM cells produced cycling endurance limits exceeding 10^{12}, or one trillion, write/erase cycles and data retention times exceeding ten years at 130°C.

Overseas Theater Optical Turbulence Measurements for the Airborne Laser

38

Payoff

The Space Vehicles Directorate recently completed seasonal measurements of optical turbulence (C_n^2) profiles in Southwest and Northeast Asia for the Airborne Laser (ABL) program. The data provided vital insight into ABL performance capabilities under realistic atmospheric conditions.

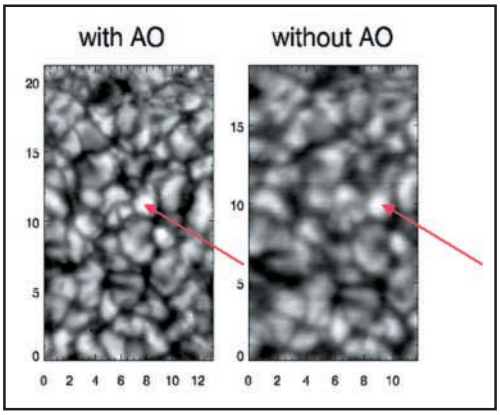
Accomplishment

Between October 1999 and June 2000 in key overseas theaters, directorate researchers measured C_n^2 from the surface to 30 km above mean sea level using balloon-borne thermosondes for the ABL program. In conjunction with congressionally-mandated airborne stellar scintillometer measurements, testing was performed. Engineers made approximately 20 complete thermosonde profiles for each location in each season during the six campaigns. The thermosonde, in addition to measuring C_n^2, also measures pressure, temperature, water vapor, and wind velocity as a function of height.

Background

Optical turbulence over long paths in the upper troposphere and stratosphere can reduce the energy reaching the target and, thus, the ABL's effectiveness. Engineers use the knowledge of the path distribution of optical turbulence to compensate for its effects by adjusting the aircraft's engagement geometry. The airborne stellar scintillometer measured the effects of path-integrated optical turbulence along long, quasi-horizontal paths representative of ABL propagation geometries in overseas locations. The coincident thermosonde measurements provide the necessary *in-situ* characterization of the atmosphere for modeling and understanding the observed stellar scintillometer behavior. Both measurements provide vital insight into the performance capabilities of the ABL under realistic atmospheric conditions.

Adaptive Optics for Solar Imaging



Payoff

A solar imaging system compensates in real time for the image blurring and distortion caused by earth's atmosphere to produce high-resolution images of the sun's surface.

Accomplishment

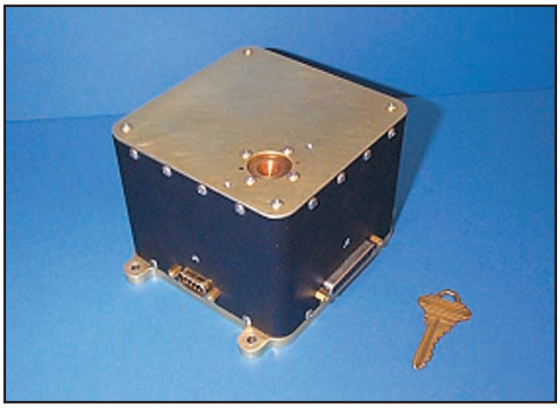
The Space Vehicles Directorate developed and installed a new system for adaptive optics imaging of the solar surface on the Richard B. Dunn Vacuum Tower Telescope (top left) at Sacramento Peak Observatory, New Mexico. The figure on the right shows simultaneous split screen images of solar granulation with the arrows pointing to the same granule, demonstrating the improved resolution in the adaptive optics (AO) view. This astronomic AO system does not require a point source and permits high-resolution solar monitoring from inexpensive ground-based telescopes.

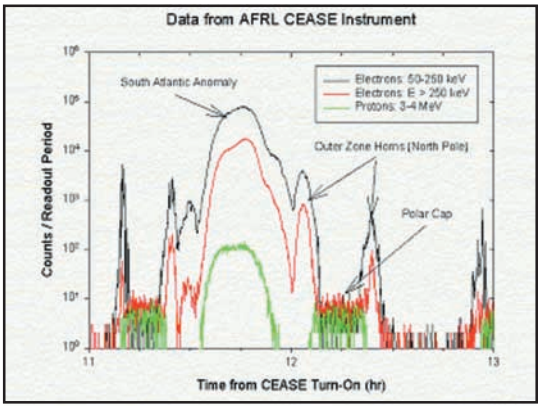
Background

Turbulence, which makes stars twinkle, creates density and moisture content variations that cause blurring of solar images. AO measures the wavefront aberrations in real time and makes corrections using a deformable or "rubber" mirror. Improved high-resolution solar images will aid in the understanding and prediction of solar eruptions that drive space weather and adversely affect Department of Defense systems.

Compact Environmental Anomaly Sensor Provides Real-Time Data

40





Payoff

Space Vehicles Directorate technology tested on the Tri-Service Experiment-5 (TSX-5) will provide spacecraft operators with real-time alerts of hazardous radiation conditions (high-energy electrons and protons from solar eruptions).

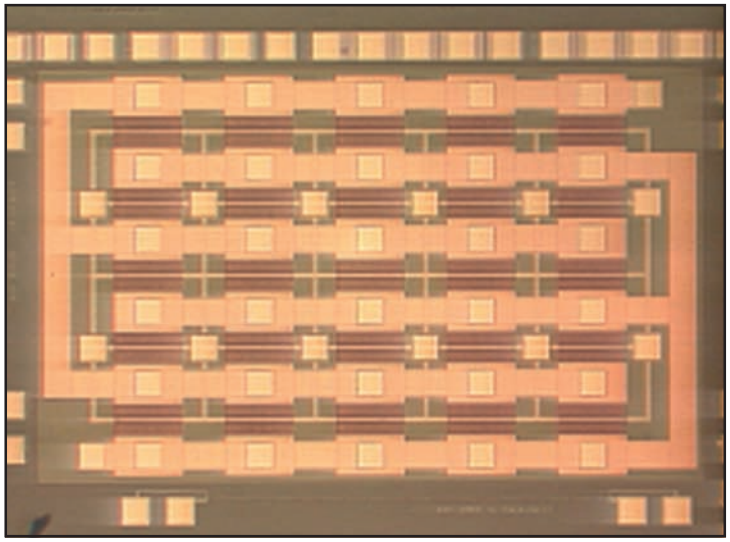
Accomplishment

The Space Test program launched the Compact Environmental Anomaly Sensor (CEASE) in June 2000 aboard the TSX-5 spacecraft into a 410 x 1740 km, 68° inclination orbit. Analysis of on-orbit data reveals that CEASE is operating successfully. The figure above shows energetic electron and proton data from a single orbit where the satellite goes through the south Atlantic anomaly and the near-earth 'horns' of the outer Van Allen radiation belt.

Background

Exposure of spacecraft to energetic particles can damage electronic parts. When anomalies occur, engineers must determine whether the cause of a given anomaly is due to natural impact from these energetic particles or from malfunctioning spacecraft electronic components. CEASE (shown above), a miniaturized suite of sensors and particle detectors, provides real-time data and warning of such hazardous conditions. Operators and engineers use data from CEASE to construct databases that improve system designs. The TSX-5 flight is the first operational test of the CEASE instrument. Other CEASE flights include the Space Test Research Vehicle 1C mission, launched in October 2000, and an advanced concept technology demonstration on the Defense Support Program Flight 21 satellite, scheduled for launch in March 2001.

Complementary Heterostructure Field Effect Transistor



Payoff

The complementary heterostructure field effect transistor (CHFET) is a new power component that significantly enhances the high-speed switching performance of the miniaturized, highly-efficient, direct current power converter, a previous Space Vehicles Directorate success.

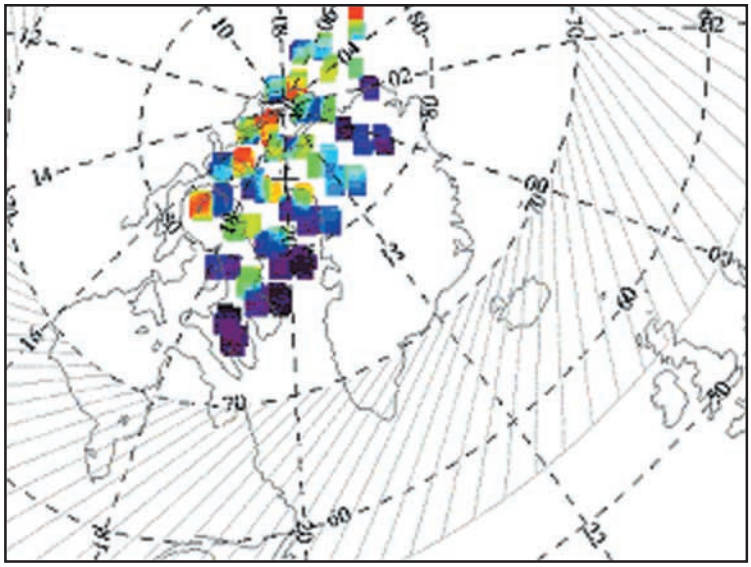
Accomplishment

A collaborative effort between the directorate's Space Electronics Component Development Group and the National Aeronautics and Space Administration Jet Propulsion Laboratory (JPL) X2000 component development program improved the fabrication process and increased yield on the complementary gallium arsenide (CGaAs) fabrication line. Engineers used the improved line to design and fabricate prototype power field effect transitors (FETs). The first complete CHFET prototypes will be integrated into directorate and JPL power converter designs. The device operates with a breakdown voltage of 20-25 volts (synchronous rectifier), achieved with a standard buffer at 120,000 electron volts (120KeV). Engineers improved the leakage current at breakdown by more than an order-of-magnitude with 120KeV low doped drain implant energy. Engineers also significantly reduced gate leakage current by thinning the gate sidewall to 0.15μm versus 0.2μm and measuring at voltage drainage to source (Vds)=0.3V.

Background

As a result of the Annual Radiation Hardened Electronics Summit in 1998, the benefits of CGaAs uses in space, their yield, and gate density problems were understood. The directorate and JPL implemented a small level of effort for a power FET. Shortly after the individual efforts began, the directorate and JPL agreed to modify the programs to provide process improvements and enhancements as well as obtain the CHFET.

Data Mapping Technique Opens Way for Polar Ionosphere Specification



Payoff

A Space Vehicles Directorate data-mapping algorithm uses the natural motion of the high-latitude ionosphere to "scan" measurements across embedded plasma density features. This allows ionospheric conditions and their impact on communication, navigation, surveillance, and other Department of Defense systems to be specified over a wide area using strategically-located, inexpensive, ground-based sensors.

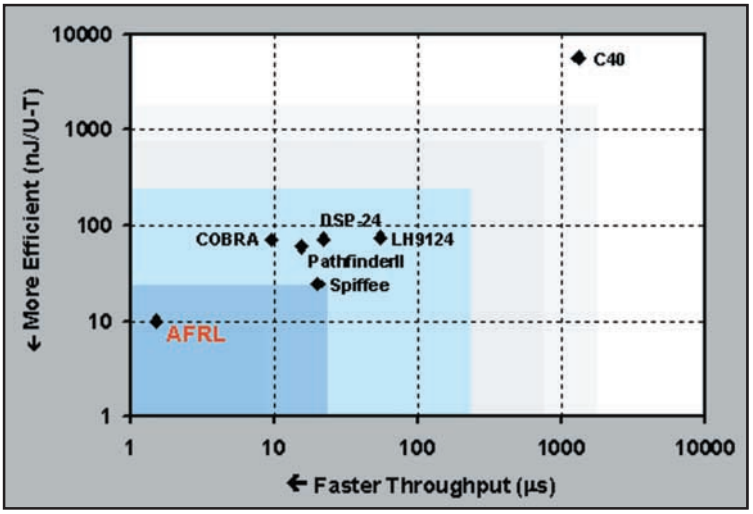
Accomplishment

The horizontal plasma density structure in the polar cap ionosphere can now be reconstructed over a wide geographic area from single point measurements of ionospheric velocity and density, using a new data-mapping algorithm. Engineers tested the algorithm using incoherent scatter radar data from the previous solar maximum, and validated the reconstructions through comparisons with independent measurements from satellite and ground-based sensors. Engineers are adapting the data-mapping algorithm to use real-time data to specify the ionosphere for high latitude, early-warning radars, whose accuracy and ability to discriminate targets are affected by ionospheric density features.

Background

The high-latitude ionosphere is in continual motion. Ionospheric plasma densities and the related disruptive effects on communication, navigation, and surveillance systems at a given location vary by orders-of-magnitude depending on whether this motion brings in high-density ionization from sunlit regions or transports low-density plasma from areas of seasonal darkness. By using measurements of the plasma motion, engineers mapped single-point data, accumulated over time, into the reference frame of the moving plasma, producing "scans" of plasma features. Engineers also combined data from two or more ground stations to provide coverage over wide areas.

High-Performance Fast Fourier Transform Processor for Space Applications



Payoff

The Space Vehicles Directorate has designed and produced the world's fastest and most efficient Fast Fourier Transform (FFT) processor that sets the stage for real-time image processing in space.

Accomplishment

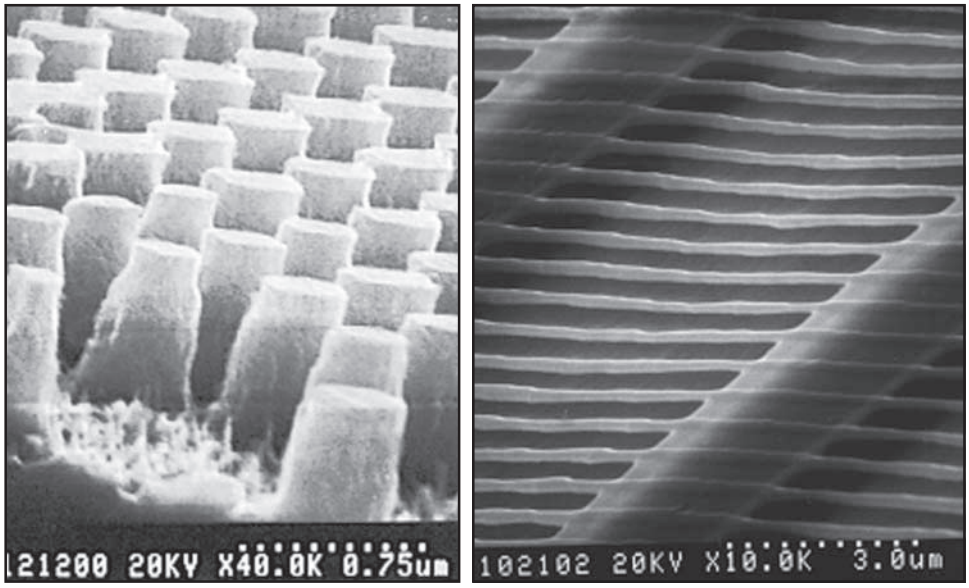
Directorate engineers combined several revolutionary technologies to implement and demonstrate an advanced technique for designing high-performance FFT processors. The FFT's framework follows guidelines set forth in an Air Force patent describing a high-performance, low-power FFT design. Engineers achieved a radiation tolerance from a low-cost commercial foundry process by using a hardened-by-design library developed by the directorate. The performance of the FFT processor offers an order-of-magnitude improvement in both efficiency and throughput over the best available alternatives.

Background

The FFT is the most widely executed transformation in digital signal processing (DSP) applications. Space-based systems requiring DSP typically use broad-level processors, which are slow and consume precious power, volume, and weight. An FFT processor based on this technology enables real-time digital signal processing at a fraction of the power, size, and cost. This technology sets the stage for in-flight data processing and eliminates the need to send raw data from satellite systems to ground stations for processing.

Nano-Scale Electronics Made Possible

44



Payoff

Space Vehicles Directorate space electronics scientists have manufactured functional nanometer-sized electronic components that are smaller, faster, and use less power than conventional state-of-the-art electronics.

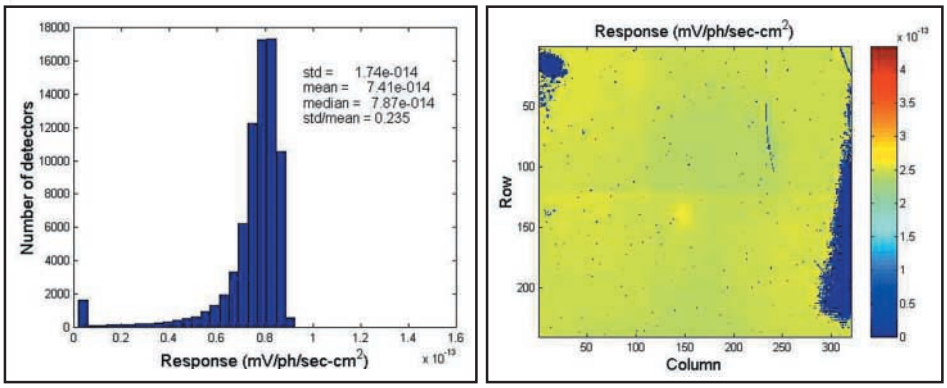
Accomplishment

Most industrial research today focuses on reducing the dimension of the fundamental electronic component - the Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) - to a critical dimension of 0.1mm. Directorate researchers successfully demonstrated that nanowire gate-all-around MOSFETs can leapfrog this dimension ten-fold. True to the needs of space electronics, the device operates at very low power (one volt) and exhibits reduced susceptibility to ionizing radiation. In addition, nanoscale gate arrays provide enhanced gate control on carriers and reduced scattering as compared to conventional planar devices.

Background

Interferometic lithography tools developed at the Center for High Technology Materials at the University of New Mexico fabricated these devices. Directorate scientists used multiple exposures and sometimes multiple photo-resist levels to create a wide variety of complex one- and two-dimensional structures. Use of these interferometic lithography tools reduce the cost of the structures.

Initial Results of Dual-Long Wavelength Infrared Waveband Focal Plane Array Development



Payoff

Space Vehicles Directorate engineers demonstrated the pixel responsive histograms for the first-ever, dual-long wavelength infrared (LWIR) waveband focal plane array (FPA). Directorate engineers fabricated the LWIR waveband FPA from mercury cadmium telluride while demonstrating imaging simultaneously in both wavebands with a format of 320 x 240 pixels.

Accomplishment

Directorate engineers working with the Naval Research Laboratory and DRS IR Technologies from Dallas, Texas achieved the first-ever dualband, infrared FPA fabricated of mercury cadmium telluride and operating in the LWIR. Testing results show the better FPAs achieve good imagery in both wavebands, with quite respectable values of response operability for the initial attempt. Specifically, directorate engineers discovered that one of the FPAs had values of pixel response uniformity greater than 95% in both wavebands. The shorter waveband (with cut-off wavelength near eight microns at the 60°K operational temperature) also exhibits a similarly high value in sensitivity operability. The sensitivity operability of the longer waveband (with cut-off wavelength near 10.8 microns at 60°K) is in the 90 percentile regime, and will be a target for improvement in subsequent developments. Independent research and development at DRS initiated several mechanical lots exploring improved interlayer contact with the aim of improving the values of operability.

Background

DRS IR Technologies developed the high-density, vertically-interconnected photodiode (HDVIP) process for single waveband FPAs. The process begins with tellurium-rich, liquid phase epitaxial growth of p-type detector material. DRS engineers dice and epoxy detector die onto six inch multiplexer wafers, populating only Grade A multiplexers. Then they make interconnects to the multiplexer "pads" with the etching of vias, followed by their metallization. During the via etching, an axial region surrounding the via is converted from p- to n-type, forming the photodiode. Advantages of the HDVIP process for dualband applications include high values of optically active area for all wavebands and exact collocation of pixels for each band; high cryogenic reliability, since the detector arrays are highly thinned and the via interconnects between the detector array and readout multiplexer are more robust than the traditional indium "bump" connections; an independent cap layer and common substrate diode architecture, avoiding flux-dependent interactions between the dualband pixels; and reduced probability of a pixel outage in one band affecting its spatial counterpart, since the two detector layers are mutually independent.

Middeck Active Control Experiment Reflight Program

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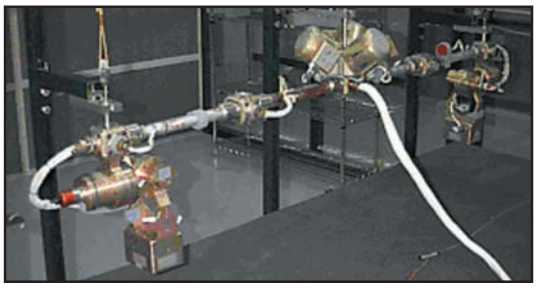
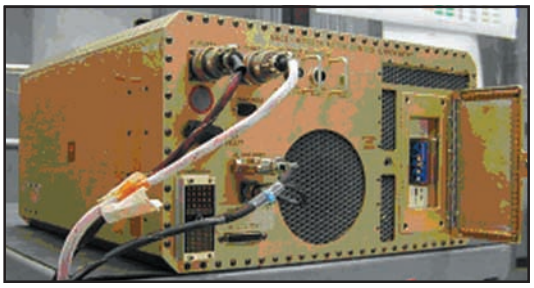




Payoff

The Middeck Active Control Experiment Reflight (MACE II) program research will result in future spacecraft with lighter, more flexible structures while still meeting ever-increasing performance requirements. Lighter spacecraft decrease overall life-cycle costs. Increases in pointing accuracy and decreases in the influence of vibration on systems provided by structural control, increase overall system performance. Finally, the adaptive nature of the algorithms developed will extend the life of spacecraft by allowing continuous mission performance as their subsystems degrade and fail.

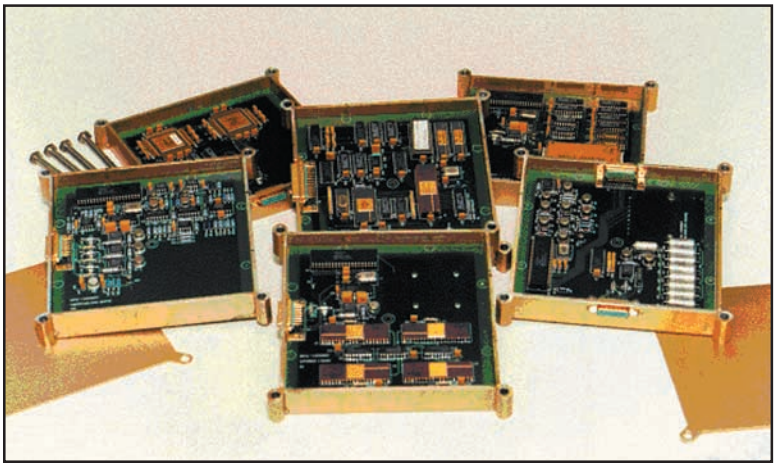
Accomplishment

MACE II will be the first demonstration of autonomous adaptive structural control tested on the International Space Station (ISS) during Increment 1 operations in space. The Space Vehicles Directorate-led science team developed autonomous, adaptive structural control algorithms to allow control of a structure without the need for extensive modeling and testing prior to use. These algorithms identify the characteristics of a structure strictly through the use of on-board sensors and actuators. Based on this information, MACE II autonomously creates its own control algorithms to suppress unwanted vibration. In addition, these algorithms can modify or adapt themselves when they sense changes in the characteristics of the system (due to changing material properties, damage, reconfiguration of the spacecraft, changes in temperature, failure of components) without human intervention.

Background

Using flight hardware developed by National Aeronautics and Space Administration (NASA) Langley Research Center, the Massachusetts Institute of Technology (MIT), and Payload Systems, Inc. of Cambridge, Massachusetts, the directorate created a highly-leveraged, cost-effective science program benefiting future Air Force spacecraft. This program has two separate science teams developing control algorithms to demonstrate vibration suppression and precision pointing of flexible structures. Using a Small Business Innovation Research contract, an Educational Partnership Agreement, and a Cooperative Research and Development Agreement, the directorate assembled an outstanding team of researchers in the area of adaptive structural control. The team includes Planning Systems, Inc. - Melbourne Controls Group (Melbourne, Florida), Payload Systems, Inc. (Cambridge, Massachusetts), the University of Michigan, Virginia Tech, and Sheet Dynamics, Ltd. (Cincinnati, Ohio). Through a second Educational Partnership Agreement between the directorate and MIT, the directorate brought in MIT to lead the second science team. The MIT-led team of Lockheed Martin, Midé Technology Corporation (Cambridge, Massachusetts), and the NASA Langley Research Center will perform research in the areas of time-varying and geometric nonlinear control. The Department of Defense (DoD) space test program (STP), managed by the Space and Missile Systems Center (SMC) Test & Evaluation Directorate, provided directorate researchers with outstanding support during the MACE II program. This program provides space flight for qualified DoD-sponsored experiments at no charge to the experimenter, via the DoD-Space Experiments Review Board. The strong working relationship developed between SMC/STP and the directorate made it possible to manifest MACE II on the ISS on very short notice when the opportunity arose.

Microsystems and Packaging for Low Power Electronics Space Experiment



Payoff

Microsystems and packaging for low power electronics (MAPLE-1) demonstrated the usefulness of commercial-off-the-shelf, low-power, reduced instruction set computer microcontrollers for launch and early orbit space applications.

Accomplishment

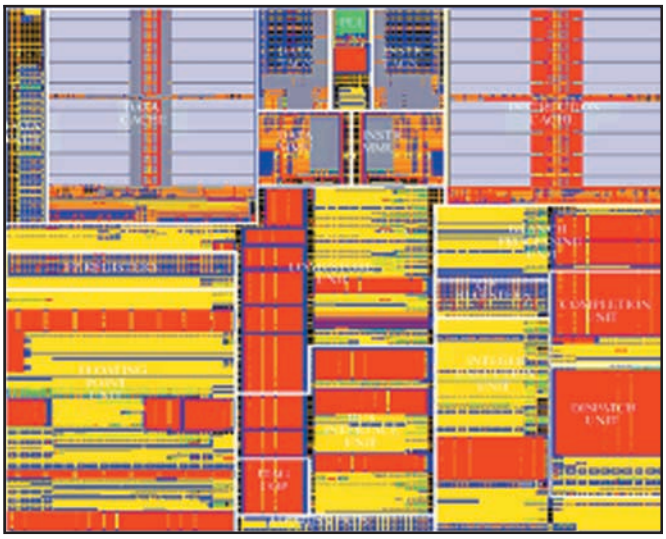
While on-orbit, the Space Vehicles Directorate's MAPLE-1 space experiment demonstrated the viability of a distributed processing scheme using commercial-off-the-shelf, low-power, low-cost processors at remote system nodes. MAPLE-1 also demonstrated advanced two-dimensional packaging techniques used in space to reduce payload mass and volume by orders-of-magnitude over conventional packaging techniques. The use of microelectromechanical systems in space and the use of advanced field programmable gate arrays in space were illustrated.

Background

MAPLE-1 comprises a series of tests to investigate the viability and reliability of critical new forms of microelectronics, two- and three-dimensional advanced packaging technology, and microelectromechanical systems in space environments. The directorate is planning to continue a series of MAPLE-1 experiments to address new developments in space electronics and contribute to the dynamic database of radiation effects and reliability data.

Million Gate Application Specific Integrated Circuit

48



Payoff

The Million Gate Application Specific Integrated Circuit (MASIC) program provides a fast, inexpensive way to create radiation-hardened, high-performance integrated circuits for space and missile systems.

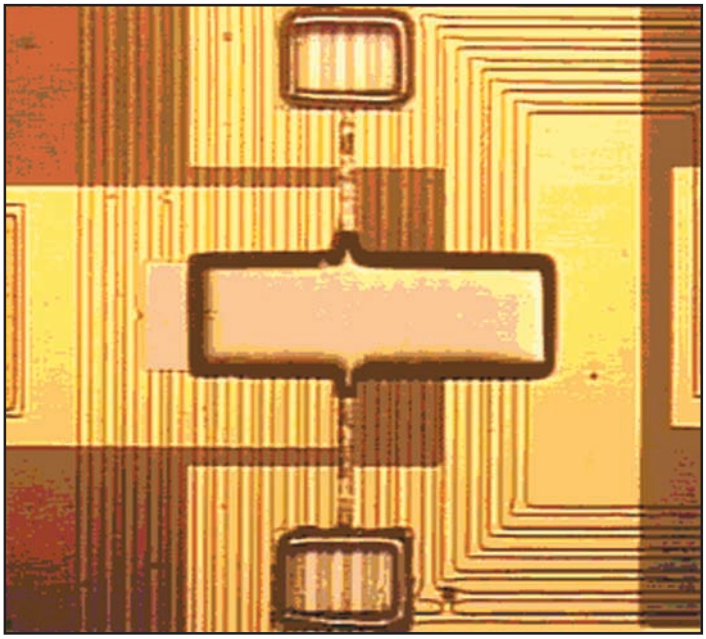
Accomplishment

The Space Vehicles Directorate established the capability to design and produce application specific integrated circuits exceeding one million logic gate integration levels based on the Honeywell HX3000 Gate Array technology. The MASIC program developed a macro-cell library; design tools for synthesis, layout, and simulation; and basic fabrication capability for space integrated circuits. Honeywell Solid State Electronics Center in Plymouth, Minnesota, established this capability to design and fabricate microchips for military, civilian, and commercial space users. Engineers will use MASIC technology to fabricate the radiation-hardened PowerPC 603e, the fastest space microprocessor.

Background

MASIC builds on the 0.35 micron silicon-on-insulator fabrication process developed by Honeywell and the Defense Threat Reduction Agency. This process provides the capability to produce static random access memory up to four million bits, and logic chips of up to one million logic gates complexity. The process yields chips that not only withstand the most demanding military requirements, but also have excellent power and speed performance characteristics. The macro-cell library established for the MASIC program contains the high-speed library, the low-power library, and the gate array library, as well as the design toolkits for the Honeywell HX3000 Gate Array. MASIC also produced evaluation chips for performance verification and characterization, and initial process optimization and yield enhancement.

Latching Microelectromechanical System Switch



Payoff

Bi-stability, the key advantage in the latching microelectromechanical system (MEMS) switch, ensures the switch remains closed (or open) when power is removed. Other advantages, such as low contact resistance, low operation voltage, good isolation, and simplicity in design and fabrication, make the device a prime candidate for applications in smart interconnects, automatic testing equipment, and other fields requiring latching relays.

Accomplishment

The Space Vehicles Directorate and MicroLab, Inc. developed the world's first latching magnetic MEMS switch. The switch is based on preferential magnetization of a permalloy cantilever in a permanent external magnetic field. Engineers used the preferential magnetization of a permalloy cantilever to achieve two stable states.

Background

Microlab, Inc. developed the latching MEMS switch under a Phase I Small Business Innovation Research contract. Engineers can embed bi-stable, MEMS-based relays in large numbers within packages, connectors, multi-chip modules, printed wiring boards, cable harnesses, and platform structures. This switch will find application in a wide range of Department of Defense and National Aeronautics and Space Administration programs as well as the commercial sector. Engineers can use the MEMS latching micro-relay in implementing a dense matrix of switches to create a reprogrammable wiring manifold. Such a manifold will contribute to the development of miniaturized, intelligent, self-repairing, and self-programming sensor systems. Because the actuator is extremely small, engineers can integrate it directly into chips, packages, multi-functional structures, and other locations in a system.

Advanced Grid-Stiffened Composite Fairing

50

Payoff

The Space Vehicles Directorate developed technology to demonstrate production of a grid-stiffened composite payload fairing. Engineers can use this nearly autonomous process to inexpensively fabricate the first grid-stiffened composite fairing ever used on a production launch vehicle.

Accomplishment

Directorate engineers and Boeing Phantom Works developed a technique to build large grid-stiffened composite structures for launch vehicle and spacecraft applications. This nearly autonomous manufacturing method uses a combination of advanced fiber placement technology and innovative tooling to allow the fabrication of large composite structures at a lower cost than previously possible. This technique also provides a great deal of flexibility in structural design, essentially allowing structural modifications between two successive parts made from the same tool. Fabricating a full-scale subsection of a new 1.5 m (61 in.)-diameter fairing for the orbital/suborbital program/Minotaur Launch Vehicle demonstrated this technique. The demonstration validated methods for fiber placement of ribs and skin, termination of ribs at the fore and aft ends of the fairing, and transition from the boat-tail section to the cylindrical section of the fairing.

Background

The manufacturing and design techniques developed in this program promise dramatic reductions in the cost of fabricating launch vehicle fairings and other structural components. Eliminating the large amount of manual labor associated with placing honeycomb sandwich in traditional composite sandwich structures will achieve this cost reduction. Increased design and manufacturing flexibility without any loss in structural performance is an additional benefit.

Mobile Processing, Exploitation, and Dissemination System

Payoff

Hyperspectral images collected by the Mobile Processing, Exploitation, and Dissemination (MoPED) system during recent exercises enabled analysts to identify vehicles from camouflaged netting and trees, discriminate US vehicles from foreign, differentiate between improved and unimproved roads, identify vehicle tracks in fields, and define other areas of disturbed earth.

Accomplishment

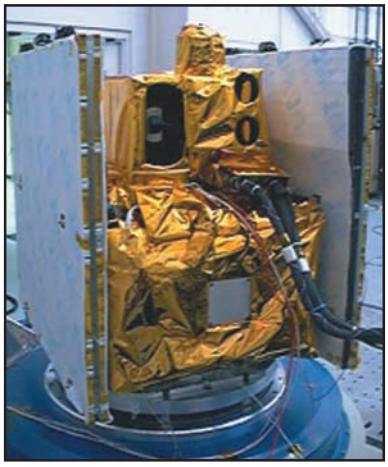
The MoPED van participated in the Forest Radiance hyperspectral image collection as part of the Air Force Space Battlelab's Hawkeye Initiative. Conducted at Ft. Belvoir, Virginia, this exercise was a dress rehearsal for an operational utility assessment for the Joint Expeditionary Force Experiment 2000. Space Vehicles Directorate personnel used the van to help train crewmembers on processing, exploitation, logistics, utility demonstration preparation, and multi-agency collaboration. Specifically, the operators processed and exploited a hypercube, collected using the Army Night Vision and Electronic Sensors Directorate Hyperspectral Airborne Reconnaissance Platform (HARP) sensor, within 90 minutes while achieving a target detection rate of 38 out of 40 targets (95%) detected with geo-location accuracies of ~20 meters.

Background

Using spectral data from various sensor sources (HARP, Sindri, and Probe 1), MoPED ingests information from these sensors; removes sensor artifacts; and performs radiometric and spectral calibration, geo-rectification, and other processing steps necessary to develop a geo-rectified reflectance cube ready for exploitation. The reflectance cube is exploited to find terrain classification, target detection, and limited target material identification. Engineers designed the van to deploy in support of exercises in various locations and environments. Eventually, use of the MoPED van with the Warfighter-1 (WF-1) Mobile Ground Station will support WF-1 user utility assessments.

MightySat II Makes History with First Fourier Transform Hyperspectral Images From Space

52



Payoff

The Space Vehicles Directorate's MightySat II satellite successfully began a one-year, on-orbit mission to prove 10 advanced technologies in space. The primary experiment is a Fourier Transform Hyperspectral Imager.

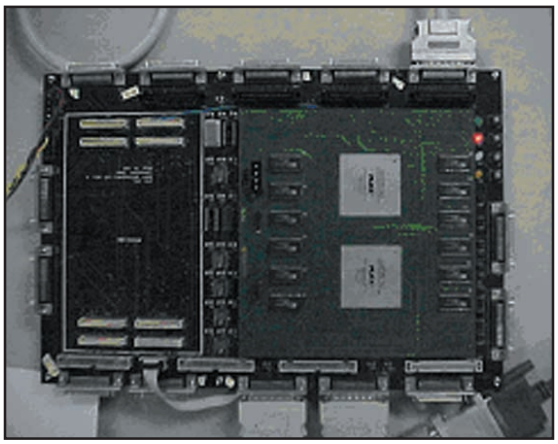
Accomplishment

In conjunction with the Department of Defense Space Test program, the directorate launched MightySat II.1 from Vandenberg AFB, California. The MightySat program is completely successful with this satellite's insertion from the orbital/sub-orbital program, also known as Minotaur 2, launch vehicle into a 570-km, circular, sun-synchronous orbit. After completing a nearly blemish-free launch and early orbit, MightySat II took its first successful image with the primary payload, Fourier Transform Hyperspectral Imager (FTHSI). The assembly of an FTHSI data hypercube and the corresponding interferogram mark the first-ever space image taken from a hyperspectral imager using Fourier Transform processing. By mid summer, process and analysis of four images were successful.

Background

The two classes of MightySat II payloads are Experimental Bus Components and Stand-Alone Experiments. Experimental Bus Components are essentially unproven hardware and include a Solar Array Concentrator, Naval Research Laboratory miniature Space Ground Link System Transponder, Multi-Functional Composite Bus Structure, Solar Array Flexible Interconnect, and Solar Array Substrate. Stand-Alone Experiment payloads manifested on MightySat II.1 include a Fourier Transform Hyperspectral Imager, Quad-C40 Processor, Shaped-Memory Alloy Thermal Tailoring Experiment, the Defense Advanced Research Projects Agency/Aerospace PicoSats, and Starfire Optical Range Optical Reflectors.

Malleable Signal Processor



Payoff

Space Vehicles Directorate engineers successfully conducted two series of real-time tests involving the directorate-developed Malleable Signal Processor (MSP) at the Kinetic Hardware In the Loop Simulator (KHILS) facility at Eglin AFB, Florida.

Accomplishment

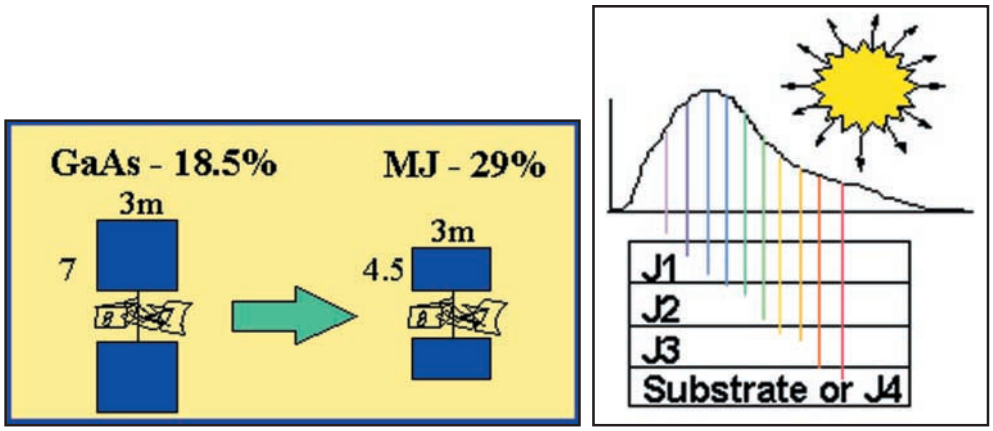
In support of the Ballistic Missile Defense Organization Discriminating Interceptor Technology program, the directorate developed and demonstrated the feasibility of exploiting reconfigurable computing in one of the first live embedded systems tests. In the KHILS test, the MSP provided real-time control of simulated infrared focal plane, lidar, and two-axis precision steering mirrors, feeding data to a fusion process also developed by the directorate. In the second test, directorate engineers substituted a real focal plane array, then built and integrated multi-chip modules of the directorate's Wafer Scale Signal Processors (WSSP) into the KHILS simulation. This marks the first simulated live test for both the MSP and WSSP systems.

Background

In normal computers, a stored program on a complex digital machine executes a sequence of instructions written in a high-level language. In reconfigurable computing, the program, which is equivalent to a "morphable" computer capable of more optimally harnessing a given quantity of silicon to perform desired functions, specifies the structure of the machine itself. The MSP differs from a variety of other reconfigurable computers due to its design to work on the bench and in an embedded system, running in real-time, which is a far more stressing application.

25-40% Efficient Multijunction Space Solar Cells

54



Payoff

The Space Vehicles Directorate sponsored the development of ultra-high efficiency multijunction solar cells that allow greater satellite payload power and mass, while reducing solar cell and solar array cost per watt.

Accomplishment

Under an AFRL Manufacturing and Technology program contract and technical direction from the directorate, TECSTAR, Inc. and Spectrolab, Inc. successfully developed 3-junction 25% efficient solar cells that provide 35% more power per area over previous state-of-the-art (18.5%) cells while reducing the cost per watt by 15-20%. A follow-on Air Force Dual Use Science & Technology project further increased the conversion efficiency to a world record 29%. Recently, AFRL and its partner in this effort, Sandia National Laboratory, received a US patent on a 4-junction (J1-J3 plus substrate or J4)solar cell design with a theoretical efficiency of 40%.

Background

Department of Defense spacecraft utilize greater power requirements today than ever before. Consequently, these complicated and diversified satellites need to run on increasingly higher levels of electrical power, provided by solar cells, for longer and more complex missions. Next-generation large satellites will place even greater demands on power systems. Multijunction solar cells convert a larger portion of the solar spectrum into electricity as compared to previous designs. To do this, use of multiple layers of semiconductors optimally absorb the sun's broadband energy spectrum. Research from this program made the United States the dominant producer of high-efficiency multijunction solar cell technologies for space.

Laboratory Operations of Dual-Band Camera with Jet Propulsion Laboratory Quantum Well Detector Technology

Payoff

A dual-band infrared focal plane array (with band centers near 9 and 14 microns) provides for simultaneous dual-band imaging (leftmost image). When operated in an integrated camera assembly, the image quality is sufficiently high to see both temperature variations on an individual's hand, as well as the radiation from the hand reflected from a metallic optics table (rightmost image).

Accomplishment

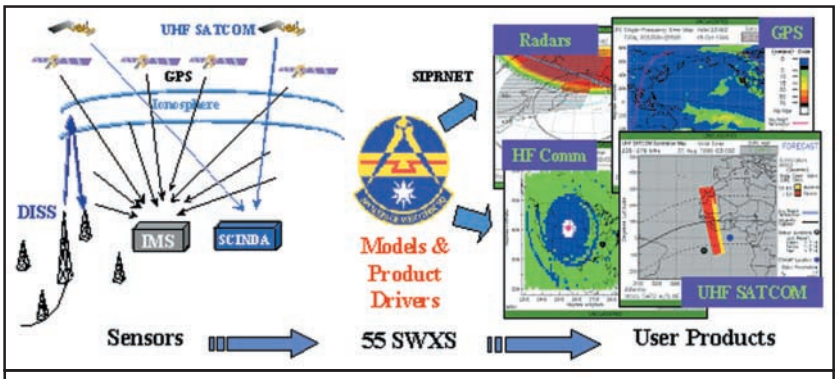
The Space Vehicles Directorate achieved a laboratory imaging demonstration capability for a novel, Ballistic Missile Defense Organization (BMDO)-sponsored, infrared focal plane array (FPA) technology. The demonstration clearly shows the low "noise-equivalent delta temperature" of laboratory sources over a large field-of-view, attained with the FPA and camera assembly, and with a new set of FPA drive and data acquisition electronics procured and configured for its operating requirements. Highlights of the improved system include independent optimization of effective brightness and contrast for the two-image displays, the capability to generate sensitivity histograms (i.e., noise-equivalent delta temperature) as a function of operational and calibration parameters, and flexibility in the display and archival of the image data. Logical follow-on steps involving field data collection include the potential collaboration with the British Defense Evaluation and Research Agency using their wavelet-based, target extraction algorithms to exploit the dual-band imagery provided by the quantum well infrared photo detection camera. Engineers also used the camera in conjunction with the directorate's new Space Scholar program (see http://spacescholars.plk.af.mil/). Ms. Diana Maestas, of the University of New Mexico was instrumental in de-bugging the remaining electronics issues associated with the camera. Notably, she identified a failed capacitor (one of many tiny components on a surface-mount technology electronics board) that resulted in a large current draw and eventually compromised circuit operation. Restoring functionality involved removing and replacing the bad capacitor. She then archived dual-band, infrared images obtained with several laboratory sources, including thermal radiation from her hand.

Background

The National Aeronautics and Space Administration's Jet Propulsion Laboratory (JPL) developed a dual-band FPA in a 320 x 486 pixel format, under directorate sponsorship and in support of the BMDO Discriminating Interceptor Technology program. JPL demonstrated the dual-band FPA that was integrated into a pour-fill Dewar.

Operational Space Environment Network Display

56



SCINDA = Scintillation Network Decision Aid
DISS = Digital Ionospheric Sounding System
IMS = Industrial Measuring System
SIPRNET = Secret Internet Protocol Router Network
55 SWXS = 55 Space Weather Squadron
UHF SATCOM = Ultra High Frequency Satellite Communications

Payoff

The Space Vehicles Directorate established the first operational space weather impact maps, creating a unique new capability and now serving as a blueprint for future space weather applications. These user-friendly graphical display maps quantify the current impact of the space environment on communication, navigation, surveillance, and other Department of Defense (DoD) systems.

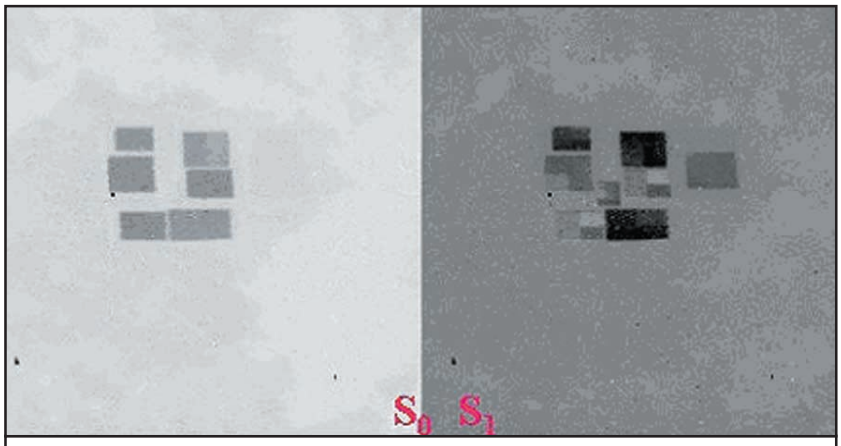
Accomplishment

The directorate provided the first operational space weather impact maps for DoD communication, navigation, surveillance, and other systems. These maps, available in both nowcast and short-term forecast mode, specify impacts, such as communication outage regions, radar clutter, and global positioning system (GPS) errors, caused by the ionosphere. These unique operational space environment network display (OpSEND) products allow DoD users to assess evolving space environmental effects and exploit this knowledge to assure availability and security of operational DoD systems. Easy-to-use web pages allow rapid access of desired product, theater, and system parameter (frequency). OpSEND integrates real-time sensor data, models, and product generators to provide both nowcast and forecast capabilities. OpSEND attracted the attention of additional operational users who are defining requirements for new products.

Background

In the past, users often misjudged space weather impacts on operational systems as equipment problems, resulting in poor system use or even outages. The user was unaware of the extent of impacts over his theater or how they might evolve. OpSEND real-time products produce both situational awareness of the profile of impacts over the entire theater and mitigation capability, such as switching communication frequency or satellites.

Using Polarization Signatures in Remote Sensing Applications



S_0 represents raw intensity or temperature in the IR. S_1 represents linear polarization. The gray painted Invar plate on the far right is visible in S_1. It is not visible in S_0 because it is the same color temperature as the background.

Payoff

The emitted polarization signature of materials is useful for discriminating targets from cluttered backgrounds. Using spectrally varying polarization signatures can identify materials or separate target and environment radiance contributions.

Accomplishment

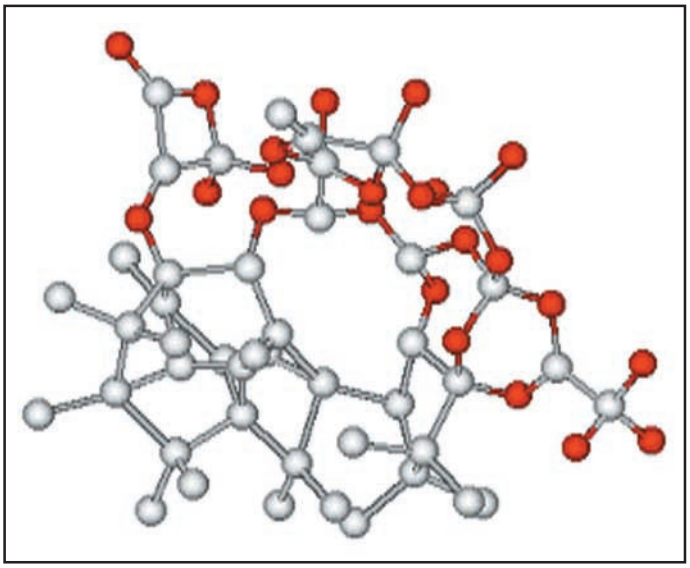
Space Vehicles Directorate researchers and contractors from Applied Technology Associates and Veridian ERIM International measured the polarization of a variety of targets in the laboratory and in the field. Data reveals significant spectral features for some materials. This is a promising start for using polarimetry in a variety of remote sensing applications.

Background

Reflection and emission of electromagnetic radiation from a variety of materials produces partially polarized light when viewed at angles from the surface. One advantage of polarization is that it can improve contrast for a number of target detection and discrimination applications. Detection of a camouflaged target from background in an isothermal scene where conventional infrared sensors would detect little or no contrast may use emissive polarization. Polarization also has the potential to distinguish between natural and man-made materials, which makes it an attractive candidate for passive surveillance and target detection. The directorate performed two experiments to determine the polarization signatures of materials using two long-wave infrared polarimeters with different designs and capabilities. The first experiment, performed in the laboratory, compared data from two instruments and showed similar results from both. In the second experiment, performed in the field, engineers surveyed the spectro-polarization signatures of many common materials and showed that some materials distinguished significant spectral features between 8 and 12 microns. Engineers are planning future experiments to measure the polarization signatures of other materials in the laboratory and in the field.

Enhanced Understanding of Space Radiation Damage in Electronics

58



Payoff

Space Vehicles Directorate scientists identified several new defects in silicon dioxide (SiO_2) and at the Si/SiO_2 interface that are critical to the radiation resistance and long-term reliability of complementary metal oxide semiconductor (CMOS) devices which are the mainstay of space electronic systems.

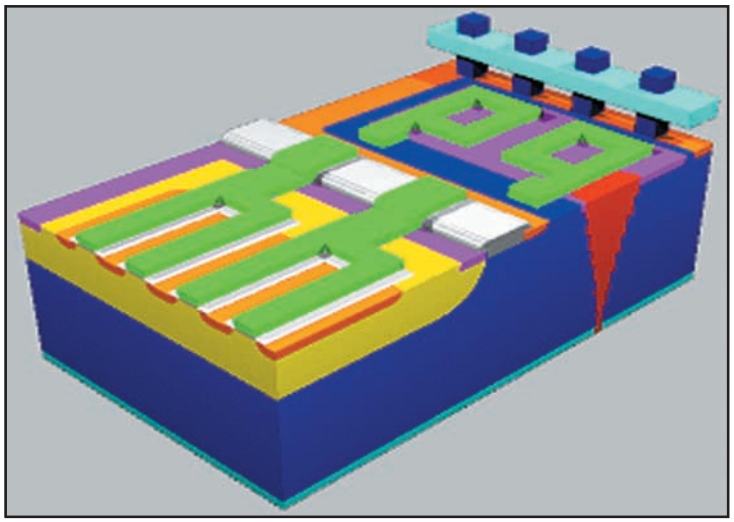
Accomplishment

The directorate's Space Electronics Research team worked for several years to understand the fundamental nature of defects and the key role of hydrogen in CMOS devices which form the basis of current large-scale integrated circuits. Using quantum mechanical techniques, the team identified several new defects in SiO_2 and at the Si/SiO_2 interface that are critical to the radiation resistance and long-term reliability of CMOS devices. Researchers also studied the key role of hydrogen in SiO_2 devices and its transport within SiO_2, both experimentally and theoretically, leading to new device concepts incorporating proton motion in SiO_2.

Background

One of the directorate's missions is the development of survivable, long-lived electronics for satellite systems. The research team's work in understanding the fundamental effects of space radiation on CMOS technology directly impacts processing and design methods in this preeminent technology. The team's efforts are an integral part of advanced development programs to develop radiation-hardened components for present and future space systems.

Cost-Saving Radiation Research for Space Microelectronics



Payoff

The Space Vehicles Directorate broke new ground with a radiation research technique permitting the most comprehensive insight into the physics of radiation and opening the door to the fabrication of new microelectronics based on predictive three-dimensional (3-D) simulations.

Accomplishment

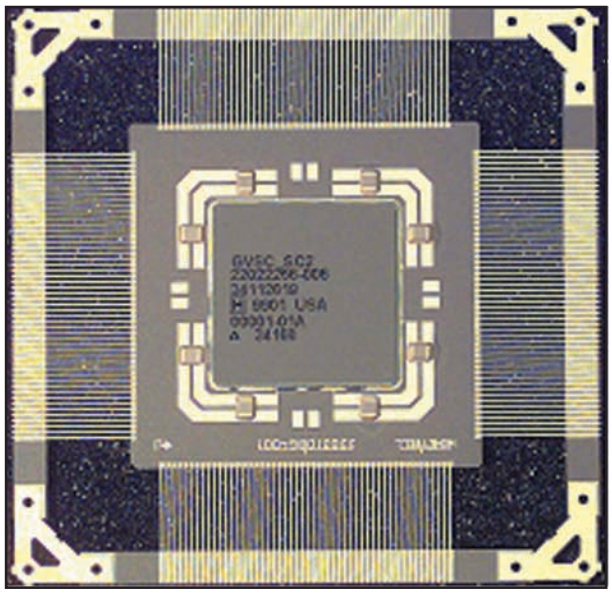
The directorate succeeded in measuring the time- and spatially-dependent response of microelectronic circuits to cosmic radiation. This measurement can discriminate the consequence of a single cosmic radiation particle strike with a spatial resolution of up to $\sim 10^{-7}$m, sufficient to map the induced effects in the most advanced microelectronics. Combined with a time resolution of $\sim 10^{-11}$ seconds, the directorate can provide the most comprehensive insight into the deleterious effects of radiation in microelectronics. This results in the most complete test of 3-D computational models to design current space and future terrestrial microelectronics.

Background

The new technique, dubbed time-resolved ion beam-induced charge collection (TRIBICC), and developed in a five-year effort with Sandia National Labs, is the most sophisticated tool ever to interpret the effects of space radiation on microelectronics. This technique is particularly important since feature sizes in commercial microelectronics will drop below 100 nm within five years. Cosmic radiation effects, currently only plaguing space electronics, will threaten the ever more susceptible terrestrial electronics. TRIBICC enables and validates physics-based microelectronics simulations and will be the only efficient and cost-effective approach to future microelectronic design.

Single-Chip within a Missile

60



Payoff

The Minuteman III (MMIII) Guidance Replacement Program (GRP) will save at least $36 million in production costs by reducing the five-chip set to a single chip. The Space Vehicles Directorate completed the single-chip generic very high-speed integrated circuit spaceborne computer (GVSC) qualification under this program.

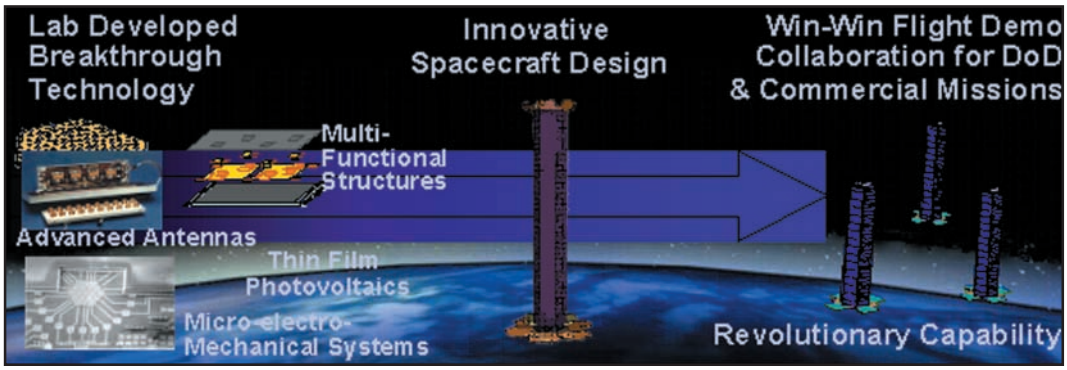
Accomplishment

The single-chip within a missile (SWAM), a collaborative program between the directorate, the MMIII system program office, and Honeywell's Space Systems Division, evaluated the suitability of the GVSC for use in intercontinental ballistic missiles. The ultimate goal of the program is to integrate the single-chip GVSC into the GRP of the MMIII system, replacing the current five-chip set. When complete, the SWAM effort will lower overall GRP production costs through greater producibility, lower support costs, and decreased schedule risk. The program also performed radiation characterization to verify the radiation hardness of the single-chip GVSC. Engineers independently validated the single-chip GVSC's radiation performance under the No-Upset Electronics Technology program.

Background

Under the Advanced Technology Insertion Module program, engineers developed the generic very high-speed integrated circuit (GVHSIC) computer by implementing the 1750A chip set. The GVHSIC computer used five individual chips in the computer, which represented a less reliable solution than acceptable. The solution was a single chip to reduce power consumption and improve performance. The MMIII program office funded the effort to reduce five chips into a single chip in order to obtain a pin-for-pin compatible replacement for their missile guidance computer.

TechSat 21 Implements Concept Car Approach for AFRL-Industry Partnership



Payoff

The Space Vehicles Directorate awarded a contract to ITN Energy Systems in July 2000 to build three TechSat 21 satellites, which became the first program to implement the "Concept Car" model for developing advanced space systems. This model reduced government cost of these satellites by over $10 million and established an AFRL-industry collaborator partnership to ensure transition of advanced technologies to future space systems, both commercial and Department of Defense (DoD).

Accomplishment

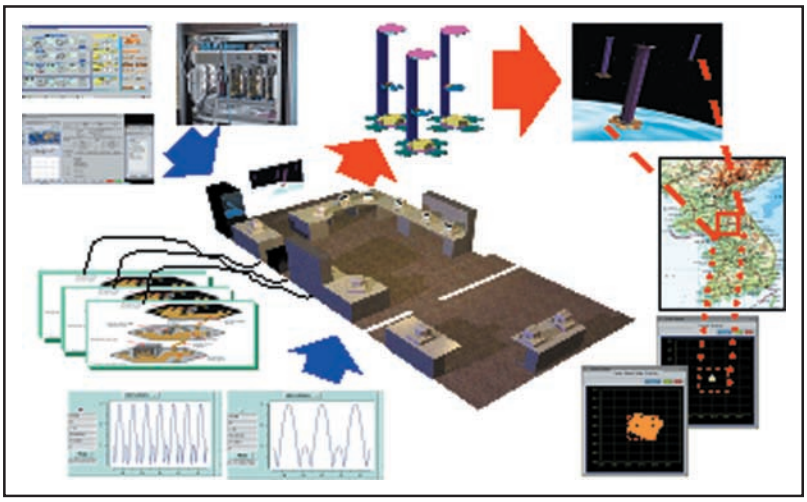
To earn this contract award, ITN Energy Systems demonstrated its commitment to the directorate's vision of revolutionary new microsatellite missions in space by fully meeting key elements of the "Concept Car" model. These elements consist of a 50-50% cost share in the development effort with an investment of over $10 million, a commercialization plan to build a business base of expanded commercial applications of microsatellites in space, and a technology transition plan to leverage state-of-the-art technologies and capabilities into future operational DoD space systems. The directorate successfully implemented an innovative non-Federal Acquisition Regulation contract allowing protected data rights and other commercial incentives to motivate a co-investment of $10 million by ITN Energy Systems as an industry collaborator in the area of microsatellites.

Background

The Air Force Scientific Advisory Board and the New World Vistas Space Technology Panel recommended that the directorate investigate the concept of clusters of microsatellites in close proximity to form a "virtual satellite" and accomplish missions typically performed by large monolithic satellites. The directorate formulated the three-satellite TechSat 21 flight experiment to demonstrate critical technologies and assess the utility of multi-mission, reconfigurable microsatellite formations performing such missions as geolocation, sparse aperture imaging, moving target indicator, and communications. This AFRL-industry collaboration is ideally structured to prove and transistion state-of-the-art technologies to microsatellite applications for both commercial and DoD missions.

Distributed Architecture Simulation Laboratory Testbed Aids TechSat21 Flight Demonstration

62



Payoff

The Distributed Architecture Simulation Laboratory (DASL) testbed, an integral part of the TechSat21 Flight Experiment program, provides critical risk reduction support in precision formation flying research, distributed sparse aperture radio frequency payload simulation, signal processing, spacecraft subsystems modeling, systems engineering and design, experiment mission analysis and planning, and mission flight software development.

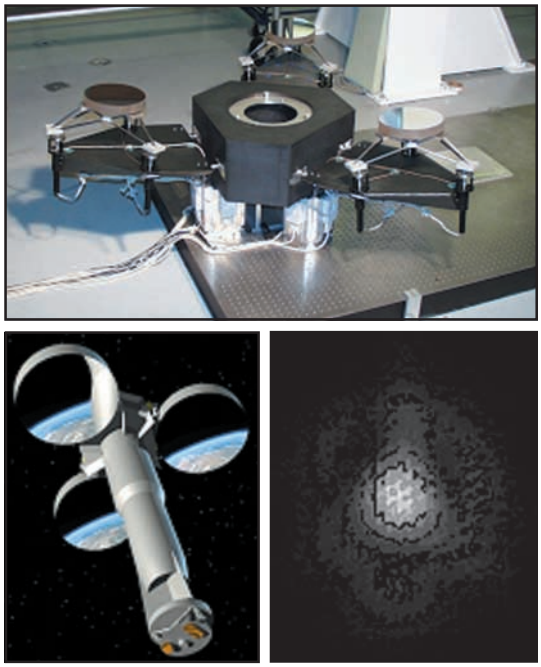
Accomplishment

The Space Vehicles Directorate opened the DASL in 2000. A testbed for the TechSat21 program was its first application. The initial, limited operational capability of the TechSat21 testbed currently provides closed-loop spacecraft dynamics and control, formation flying, and radar beam pattern assessment for a cluster of microsatellites flying in formation and operating in unison as a "virtual satellite" to perform its mission.

Background

Pushing the state-of-the-art in spacecraft and payload technology development and conducting a space flight experiment drives the need for risk, cost, and schedule reduction activities. Among these, a modeling and simulation testbed is critical to support the design, integration, and test of technology before flight and conduct mission utility studies with validated models after flight demonstration for possible acquisition decisions. The directorate built the DASL testbed, a hardware- and software-in-the-loop, end-to-end simulation system, as an enduring capability for assessing laboratory technology. Specifically for the TechSat21 program, the testbed is developing models and simulations of frequency and time-domain radio frequency systems; associated background/target scenes; natural and mission-related environmental effects; global positioning system signal generation, guidance, navigation, attitude determination; metrology subsystems; and autonomous command and control through the ground-to-space segment. The testbed also includes an 8-PowerPC flight processor cluster with a real-time operating system used as a hardware-in-the-loop emulation for developing and testing flight software and flight algorithms built in the space and ground segment simulation environments.

UltraLITE Performs First Autonomous Phasing of Sparse-Aperture Mirror



Payoff

The Space Vehicles Directorate's UltraLITE program performed the first autonomous phasing of sparse-aperture telescope primary mirror segments on a realistic, lightweight space structure. This achievement represents a critical step toward cost-effective, large-aperture optics in space.

Accomplishment

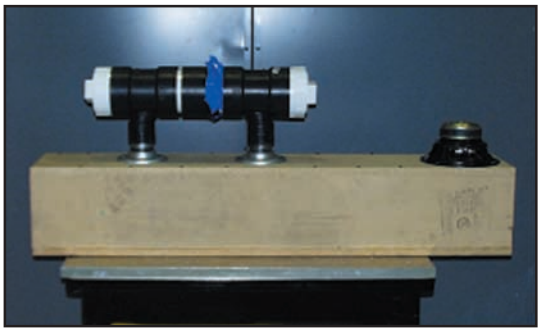
In July 2000, the directorate's UltraLITE team demonstrated the first autonomous phasing of the three 20cm sub-apertures comprising the primary mirror for the Deployable Optical Telescope testbed. From an initial misphased and misaligned position, limited only by the range of the sensing and actuation systems, the computer-controlled system brings the mirrors into an aligned and phased position utilizing a white-light interferometer truth sensor without any required operator input. The directorate's testing demonstrated that phasing is accomplished within 10 nm (1/5000th the width of a human hair) of the theoretical values (zero optical path difference in center-of-curvature test configuration).

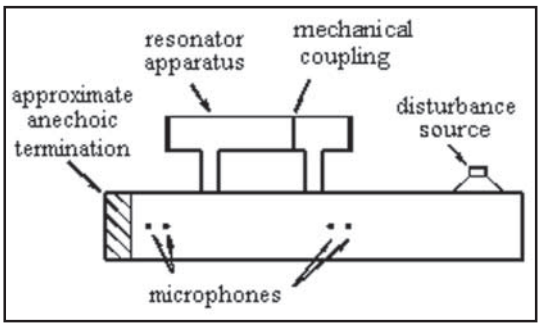
Background

In 1995, UltraLITE began to develop technologies vital to future Department of Defense requirements for large space-based optical systems such as the Space-Based Laser system. Current launch vehicle shroud and weight constraints limit the primary mirrors of such systems to less than five meters, limiting systems to low-earth orbits, which in turn necessitates large, expensive satellite constellations to provide global coverage. The directorate's UltraLITE provides an integrated ground demonstration of technologies to allow storage of future optical systems for launch, and deployment on-orbit to their operational configuration. The directorate is researching specific technologies such as lightweight mirror structures, stiffness-critical precision composite structures, advanced control system architectures for autonomous phasing and maintenance, and precision mechanisms for deployable space optics applications.

Mechanically-Coupled Helmholtz Resonators

64





Payoff

Eliminating unwanted acoustic energy within space vehicles during launch is critical to the placement of sensitive payloads into orbit. High acoustic levels result in harsh vibrations that damage satellites and can render them inoperable at the cost of billions of dollars. For their research in this important area, Dr. Steven Griffin and Dr. Steven Huybrechts received a US patent for the development of coupled Helmholtz resonators for broadband acoustic attenuation.

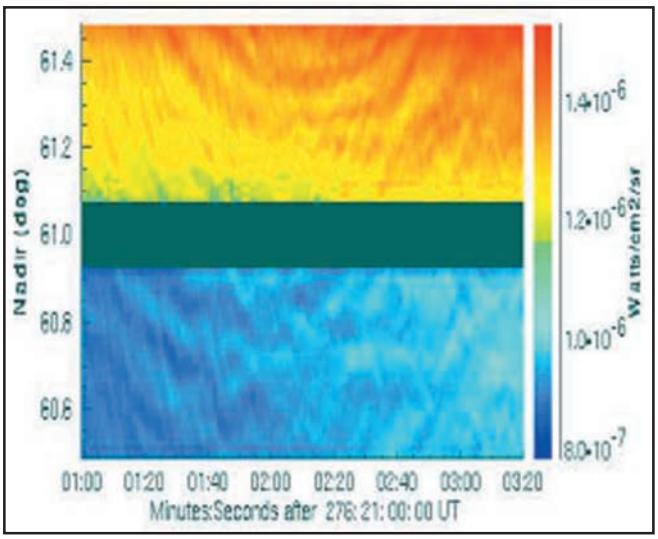
Accomplishment

Mechanically-coupled Helmholtz resonators, a developing technology, employs the understanding of both acoustics and structural-borne vibration to mitigate acoustic transmission. This technology is especially advantageous in applications such as launch vehicles where increased payload protection is necessary and where strict mass and volume limitations exist. Lower acoustic transmission inevitably translates into protected payloads and consequently lower launch costs for space launch vehicles. Space Vehicles Directorate researchers developed and validated fully-coupled structural-acoustic models of mechanically-coupled resonator systems. The directorate's laboratory tests of mechanically-coupled resonators mounted on low-frequency impedance tubes demonstrated increased levels of acoustic attenuation (12 dB) over wider frequency bandwidths, relative to conventional, uncoupled resonator devices. Experiments also demonstrated the feasibility of incorporating active materials in the coupled resonator system to create "smart" structures capable of adaptively canceling disturbances of varying frequency. Transition and integration of this technology into advanced multi-layered structural systems, such as ChamberCore, will provide testing and evaluation. This technology, an evolutionary step in the development of multifunctional structures for launch vehicles, resulted in a patent as well as conference and journal papers.

Background

Mechanically-coupled Helmholtz resonator technology is part of the overall directorate's effort to explore innovative ways of reducing acoustic transmission in launch vehicle shrouds. The amount of acoustic transmission directly relates to the testing requirements that payloads must meet for launch. Engineers must over-design the spacecraft to meet acoustic launch requirements by adding weight, cost, and complexity to already complex systems.

Mid-Course Space Experiment Observation and Analysis of Thunderstorm-Generated Waves Prompts Spin-Off



Payoff

Recent radiance measurements in the mid-wave infrared by the Mid-course Space Experiment (MSX) enabled the initial design of a new sensor for measuring the characteristics of atmospheric waves from space. This is the initial phase of a major program to obtain further details on waves, which are key sources of clutter to space-based surveillance systems looking through the atmosphere. The new measurement program will be of great assistance in gaining further understanding of the generation and propagation of waves in the atmosphere, and in developing models describing wave structures for use in clutter mitigation for surveillance systems.

Accomplishment

The Space Vehicles Directorate recently accomplished the initial design of a new space-based sensor for measuring waves in the stratosphere as part of a National Aeronautics and Space Administration two-year study grant. This sensor may lead to a major program (WAVES EXPLORER) to understand the character of atmospheric waves seen from space and will also provide models of waves in the atmosphere, which can be used in Department of Defense atmospheric radiance codes and system clutter mitigation tools.

Background

The sensor design resulted from an earlier MSX discovery of atmospheric waves in mid-wave infrared measurements of the stratosphere from space. Generated by such sources as thunderstorms and winds, these waves are now considered a major constituent of background clutter seen by infrared surveillance systems looking through the atmosphere.